Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1349

Washington, D. C. ▼ September, 1925

THE BROOD-REARING CYCLE OF THE HONEYBEE

By

W. J. NOLAN, Associate Apiculturist
Division of Bee Culture Investigations, Bureau of Entomology

LIBRARY
BUREAU OF
OCT 17 1925
AGRICULTURAL ECONOMICS
DEPARTMENT OF AGRICULTURE

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1925

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1349

Washington, D. C. ▼ September, 1925

THE BROOD-REARING CYCLE OF THE HONEYBEE

By W. J. Nolan, *Associate Apiculturist, Division of Bee Culture Investigations, Bureau of Entamolgy*

CONTENTS

INTRODUCTION

In previous work of the Bureau of Entomology emphasis has been placed on the conditions necessary for the proper wintering of bees, in order that colony population and energy may be conserved to the utmost during the period when no brood is reared by normal colonies. It is evident, however, that merely wintering the bees in the best possible condition will not in itself guarantee that the colony will at the right moment have the proper strength and composition for gathering a maximum honey crop. Nevertheless, if, through proper wintering, the strength of the colony has been adequately conserved, the resumption of brood rearing in the spring may take place at the proper time and the amount of brood reared may increase at a remarkable rate, since the ability of the colony will not have been impaired through excessive work during the winter. It is appropriate, therefore, that the investigation of wintering conditions should be followed by an investigation of the factors which modify brood-rearing activity, more especially those which are under the control of the beekeeper.

Since normally a worker bee, before going to the field, spends the first two or three weeks of its life in duties within the hive, the quantity of nectar gathered by any colony depends not merely on the total number of bees in the colony during a honey flow, but on the number included within that total which represents bees of proper age to serve as nectar gatherers. In order to have the largest possible number of field bees at the proper moment, therefore, the highest daily rate of bees emerging from the brood cells during any given season should

occur about three weeks in advance of the main honey flow; in other words, the queen should reach her maximum daily egg-laying rate during the period six weeks prior to the honey flow. Since in a colony left to itself such is usually not the case, a correct understanding of the principles governing brood rearing throughout the year becomes of prime importance to the beekeeper, if he is to handle his colonies in such a way as to secure a maximum honey crop.

Lack of knowledge of the principles governing brood rearing may cause a reduction in the honey crop by bringing about in a colony any or all of the three following possibilities:

1. The population of the colony may not become large enough to provide sufficient field bees during nectar flows to gather surplus adequate to give the beekeeper a fair return for time spent and capital invested.
2. Surplus honey may be consumed in regions of early nectar flows by bees which have emerged too late to serve as nectar gatherers, and too early to winter over or even to assist in building up the colony for winter.
3. Swarming may be stimulated if the ratio between hive bees and field bees does not remain such as will avoid causing a congestion within the hive whenever one of these classes is relatively idle while the other is extremely busy.

The prevention of any or all of these states involves such questions as wintering, stores for spring, requeening, population of the colony at the beginning of brood rearing, swarm control, dequeening, removal of brood, and other related factors. In short, regardless of its immediate purpose, every sound beekeeping practice having to do with the actual manipulation of the colony itself has as its final result the elimination or prevention of some one of the three above-mentioned conditions. The utility of any manipulation of the colony may well be gauged by the extent to which such an outcome is achieved. It is essential, then, to have a clear understanding of the principles of brood rearing in order to apply the proper procedure to any case so as to obtain the desired result.

The manner of increase in a colony's population has been under discussion since the days of the ancients. Views on this subject prior to the latter part of the seventeenth century, however, differed widely from those now held, since the sex of the queen had not yet been determined and many people even believed in the spontaneous generation or creation of bees. That brood rearing is a phenomenon in which the queen is concerned directly was not generally recognized until Swammerdam (*14, p. 159*)[1] in 1669 established clearly the actual relationship borne by the queen to any increase in the colony's population. Since this great apicultural discovery, beekeeping literature has been filled with reports and conjectures as to a queen's daily egg-laying capacity, and the total amount of brood reared during a season. Among early investigators in the field, Reaumur (*13, p. 475*) in 1740 stated that the height of egg laying comes in the spring and that over a period of two months at that time the queen may average 200 eggs per day, this average being accepted for nearly a century afterwards as fairly typical of a queen's egg-laying capacity.

---

[1] Reference is made by number (italic) to "Literature cited," p. 37

The first trustworthy determination of the number of eggs laid in a single day was made by von Berlepsch (*3, pp. 68–69*) in 1856. Having succeeded in confining the egg-laying activity of an especially prolific queen to a single comb for 24 hours, he found that meanwhile 3,021 eggs had been laid. An estimate of the amount of brood remaining in the hive to which the queen belonged led to the assumption that she had been averaging nearly 3,000 eggs daily for the preceding 20 days. During the remainder of the nineteenth century this rate was widely accepted as a proper index of a queen's daily egg-laying capacity, although von Berlepsch himself believed such a rate to be exceptional, and that a daily average of only 1,200 is probably usual. Inasmuch as this particular queen was active for five seasons, von Berlepsch assumed that she must have laid at least 1,300,000 eggs during her lifetime, a number which apparently has served many later writers as a basis for their estimates of the total possible egg-laying achievement of a queen. Baldridge (*2*), an American contemporary of von Berlepsch, deserves mention because he furnished the first published census of all the eggs, larvæ, and sealed brood in a modern hive, determined by an actual count. He even entertained the idea of counting all the eggs in a certain colony every 72 hours, but apparently never carried it into effect.

The first authentic data as to the total number of eggs laid by a queen throughout an entire season were published by Desborough in 1852 (*8*). In 1855 (*9*) he published data in regard to the number of eggs laid by one queen in two successive seasons, and in 1868 (*10*) he presented similar data covering six successive seasons for a single queen. Desborough's figures were obtained by making periodic estimates of the area occupied by brood. The colony used seems to have been so much below normal strength, however, that his findings can not be taken as typical. For the next 40 years, of the many reports on the quantity of brood found in a hive, or of the daily egg-laying capacity of a queen, few are of any real value in understanding the annual brood-rearing cycle. Interesting as they may be, these reports too often represent only the performance of some exceptional queen during a single day at the height of the season. Such sporadic endeavors, either in themselves or in relation to other similar reports from localities under far different conditions, afford little basis for drawing conclusions as to brood-rearing activity throughout a whole season. Although during this long stretch of years it may have been realized that the annual brood-rearing cycle can be determined only by continuous observations on the same colonies during any given season, apparently no one undertook the task. Finally, in 1895, Baldensperger (*1*) furnished the first published results of successive counts or estimates throughout the year of the quantity of brood in a colony of normal strength.

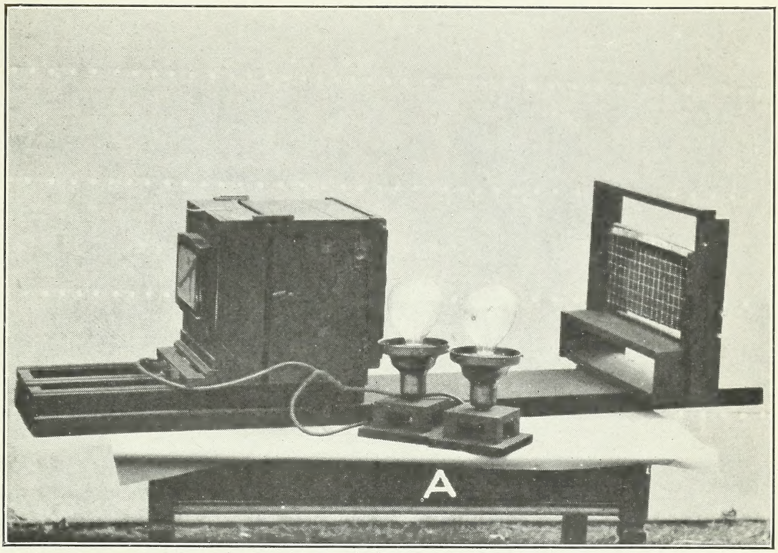
An epoch in this line of research is marked in 1901, when Dufour (*11*) published data obtained from the first comprehensive study of the subject by a scientific method of approach. As a result of four years' work he had secured seven seasonal brood-rearing records by actually counting, at intervals of approximately 21 days throughout each season, every egg, larva, and sealed brood cell in each colony used. In 1912, the first seasonal curves based on results from brood-rearing investigations were presented by Brünnich (*4*). In 1919 (*5*), and again in 1922 (*6*), he presented other

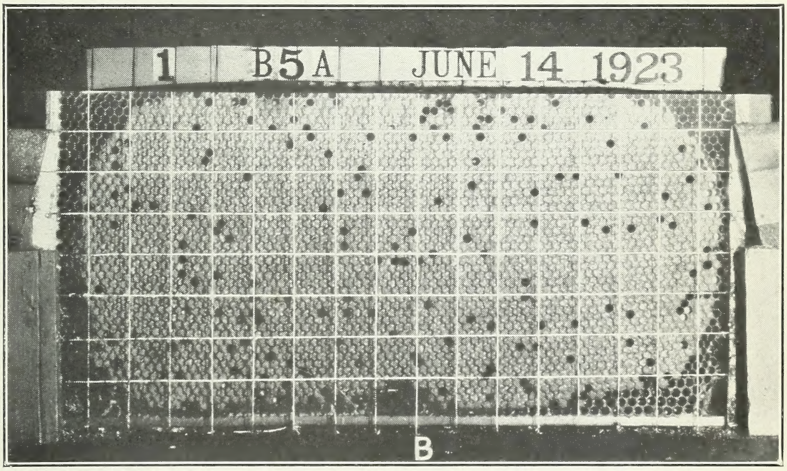
similar curves, representing the daily egg-laying rate of various individual queens. Brünnich's work, unlike Dufour's, is based, not on an actual count of each cell containing brood, but on a mathematical calculation of the number of such cells derived from linear measurements of the brood area on each frame throughout the season. From data thus obtained daily egg-laying rates are calculated for the whole season. Although the claim can not be made that Brünnich's work is as nearly accurate as Dufour's, the Swiss investigator has adopted a method which is fairly speedy and readily utilized, and which gives results reliable enough for most purposes.

METHOD

In 1920 work on this problem at the Bee Culture Laboratory was first begun when Lloyd R. Watson, formerly apicultural assistant, made actual counts weekly of all eggs, larvæ, and sealed brood in five colonies for the entire season. Any such method of counting brood on each comb is necessarily slow. In cool weather it involves the possibility of brood becoming chilled before the operation is completed; at other times there is danger of robbing, and in any event there is too long a disturbance of the colony. Accordingly, when the writer took over the work at the beginning of the season of 1921, a photographic method was determined upon, whereby photographs are taken weekly of every frame containing sealed brood, and counts are made later from the negatives. Only sealed brood is counted, because of its greater clearness on the negatives. As a result of the use of this method, photographic records of 16 colonies were obtained in 1921, and of 32 colonies in 1922. Adding to these the counts from the five colonies in 1920, the equivalent of a total of 53 individual seasonal brood-rearing records has been obtained already from the work now in progress.

A small building adjacent to the apiary not only houses the camera permanently but also affords protection from robber bees while taking the pictures. During exposures two 500-watt electric lamps furnish light sufficient to obtain good negatives at all times within the building, regardless of conditions of light outdoors. The camera itself is fastened securely to one end of a base made of 2-inch plank. To maintain the brood frames firmly in position during exposures and yet to have in the negative an image of every cell on the exposed side of each comb, a substantial holder (Plate I, A) is used which consists of a base with two uprights at each end, the uprights being joined by a top piece. The width of the holder is such that the lower half of each end bar of a Langstroth frame just fits into a groove extending upward from the base on the inner surface of each upright. A super spring fastened to the rear edge of each groove presses the end bar firmly against the front edge, and thus the brood frame is held rigidly in a definite position, although it may easily be slipped in and out of the holder. The holder itself is fastened securely to the same base as is the camera, but at such a distance from the lens as to give a reduction to a scale two-thirds that of the original. Because of the uniform focal distance and the uniform illumination, all negatives are made on an identical scale and under the same light conditions. By the aid of a suitable device attached to the frame holder there is photographed with each frame of brood a record showing the date, the hive and hive body from which the frame came,





PHOTOGRAPHIC PRODUCTION OF BROOD RECORDS

A.—Apparatus used in obtaining records, showing camera, brood-frame holder with brood frame in position, wire net, record, and electric lamps. B.—Print made from a photographic record, illustrating the character of a permanent record

the location of the frame in the hive body, and the particular side of the frame. A net of wires forming 1-inch squares is permanently fixed to the holder at such a point as barely to clear the surface of any brood frame in the holder and still be in focus. The squares, showing clearly in the negative (Plate I, B), divide the brood area into such small sections as to render possible an extremely accurate, direct count.

For recording the counts from each negative, a card is ruled into squares identical in size and number with those in the picture itself. All squares corresponding to areas containing only sealed worker cells may be credited with the number of cells contained in 1 square inch; but in squares containing unsealed as well as sealed cells, the number of unsealed cells must be deducted first. There are many contradictory statements as to the number of cells per square inch, due in part to attemps to derive it mathematically from the dimensions of some single cell instead of counting the actual numbers in areas large enough to get a trustworthy average. Watson, by making such counts, found the average number per square inch to be slightly in excess of 26. This number has been used in the results presented here. Some variation exists between individual combs, however, possibly due to the foundation used. Thus, in combs from certain foundation the writer has found 26.3 worker cells per inch, and in combs from foundation bought after the results for 1921 were obtained he has found approximately 27 worker cells per square inch. Much of this latter type of foundation has been used since that date, and subsequent results are therefore being calculated on this basis. It is very evident that the general relations of a curve based on the amount of brood counted will remain the same, regardless of whether in the counts the number of cells per square inch is taken to be 26, 27, or some other figure of nearly the same size. As a matter of fact, the difference between 26 and 27 is less than 4 per cent, or less than 40 in every 1,000.

In areas containing 50 per cent or more of unsealed cells it has been found preferable to count each individual sealed cell. Sealed drone cells also are counted individually. They have little influence on the totals, however, because by proper selection of brood combs it has been possible to keep the total of sealed drone cells well below 600 on any one count. Since in counting individual cells, either sealed or unsealed, some arbitrary rule must be followed in crediting them to a particular square; all such cells are credited to, or deducted from, the total of the square immediately to the left of the vertical dividing line, or below the horizontal dividing line, as the case may be. Totals for each card and colony are calculated on an adding machine. The photographic record once obtained, the actual counting may be delayed until any convenient time, so long as the negative does not deteriorate. A series of such records permits making a year-by-year comparison of any portion of the sealed-brood area. Cut films, 5 by 7 inches in size, are used exclusively in this work.

Before photographing, all of the frames containing sealed brood in any given hive body are shaken or brushed free of adhering bees, placed in an empty hive body, and immediately carried to the building where the photographs are made. The exposures can be made in 10 seconds, thus keeping the frames out of the hive for an exceedingly short time. Danger of chilling the brood is thus reduced to a

minimum, although in any event, in the cooler weather of spring or fall, there are few frames containing sealed brood. The hive being open for so little time, danger from robbing is also reduced, and the normal activity of the colony is disturbed to a far less degree than is the case in any other method of brood-area determination so far employed. The great speed with which the work can be accomplished adapts this method to investigations on a large scale. In the first two years of this work more than 18,000 pictures were thus taken.

DEFINITIONS

The term "brood nest" as used in this bulletin applies to the space occupied by brood, regardless of the number of hive bodies in which brood is found. The term "brood area" is similarly applied. The term "super" is used for the hive bodies which are placed above the second hive body to give additional room for colony activity, the lower two hive bodies being those which remain with the colony permanently, summer and winter. The hive bodies are of uniform size, regardless of purpose. Brood could be reared in the supers of hives in which no restriction was placed on the movements of the queen by a queen excluder. In the apiary of the Bureau of Entomology, where this work was done, the colonies are arranged in groups of four for convenience in putting them into packing cases for winter, and such groups are referred to as packing-case groups. The term "quadruple packing case" refers, of course, to the fact that each of the packing cases used is capable of containing four colonies. "Nectar flow" and "honey flow" are used synonymously to cover those periods in which nectar available for the honeybee is secreted freely. "Pollen yield" refers to the gathering of pollen in large quantities. The term "natural requeening" is used in this bulletin for the requeening of colonies in which it is impossible to determine whether the old queen was lost through natural supersedure or whether she was accidentally killed while the colony was being handled. Where artificial requeening was practiced, as by the killing of the old queen and the giving of a queen or queen cell, the period of queenlessness is less than in natural requeening.

ANNUAL BROOD-REARING CYCLE

Common recognition of certain factors underlying brood rearing has given rise to different apiary practices. For example, it has long been believed, regardless of geographical conditions, that a honey flow greatly stimulates egg laying. This is attested by such apiary practices as dequeening during a honey flow, removing brood, and the like. Although apiary practice has contributed much to a knowledge of brood rearing, it has not as yet furnished a clear, definite understanding of all of the factors causing an increase or decrease of brood-rearing activity. For instance, it has not been established as a fact that brood-rearing activity increases in a uniform and regular manner during the beginning of the active season, nor that irregularities may then occur. In short, each seasonal phase of brood rearing presents problems, not fully solved as yet, which are of vital importance in beekeeping practice.

It is a matter of common apiary experience that during a certain portion of the year, depending on weather, nectar flows, and other

conducive factors, brood-rearing activity is prevalent, and that in the remaining portion of the year brood-rearing activity is suspended. The annual brood-rearing cycle may therefore be divided into two parts: (1) a period of seasonal activity and (2) a period of seasonal suspension. The period of seasonal brood-rearing activity, or the "active season," takes place, roughly speaking, during the summer; the period of seasonal suspension of brood rearing, here called the "inactive season," occurs in winter.

SEASONAL ACTIVITY

At the end of the inactive season, marked normally by the first incoming nectar or pollen, brood rearing is resumed and may proceed to a certain maximum in the fore part of the active season at a rate which is often strikingly noticeable. Brood-rearing activity during the remainder of the active season, up to the period of final decline, varies widely with geographical location or climatic conditions. In some regions it is maintained at a uniformly high rate throughout; in other regions it is broken in continuity by an interval of partial suspension. In still other regions there is a gradation between these two extreme types of seasonal brood-rearing activity. The final decline is either abrupt or gradual, depending also on geographical location. Regardless of geographical location or climatic conditions, the period of seasonal activity may be divided into the three following phases: (1) A period of initial expansion, (2) a major period, (3) a period of final contraction. It is not always possible to draw a sharp line of demarcation between these three seasonal phases of brood-rearing activity, because external environment, such as weather or incoming nectar and pollen, often causes the end of one seasonal phase to become so merged with the beginning of the next that the initial influence of the succeeding phase can not easily be detected.

PERIOD OF INITIAL EXPANSION

The initial expansion covers that period of the active season immediately following the inactive season, in which brood-rearing activity is normally resumed and is continued in spite of conditions which if occurring later in the season would tend to check brood rearing. It should be pointed out that the beginning of brood rearing here discussed is that caused by the incoming of the first nectar or pollen and does not apply to abnormal brood rearing during the inactive season, which will be discussed later. At no other time in the year does the tendency to rear brood seem so persistent as during this initial phase, except possibly when a colony has just swarmed or when a queen is beginning to lay for the first time. Although the rate of increase in brood-rearing activity may be greatly accelerated during the period of initial seasonal expansion by incoming nectar or pollen, the fact that such an expansion continues after resumption of brood rearing, even with no incoming nectar or pollen, indicates that this phase is purely seasonal and needs only the approach of spring to cause its appearance.

Since this expansion in the spring is a seasonal phenomenon, and is bound to occur, the colony which will gain the most rapidly in population in the spring is the one possessing the largest number of factors favorable for brood rearing. It becomes readily apparent,

then, how important it is for the beekeeper to do everything in his power to have conditions in the hive just right at the moment this phase begins, if his colony is to get a good start from the very beginning of the season. Such action on the part of the beekeeper is especially imperative in regions where the honey flow follows close upon the opening of the active season, because under such circumstances little time is given the colony in which to build up, and such time as is granted must be used to best advantage. In localities with early honey flows a successful season is dependent largely on the number of bees reared in the period of initial expansion.

Regardless of any direct bearing upon the honey crop, it is to the advantage of the beekeeper to make the most of the tendency toward greatly heightened brood-rearing activity during the period of initial expansion, merely for the sake of having his colonies strong enough to resist certain diseases successfully. A colony which has gained a maximum population during the initial expansion is in a far better position to ward off European foul brood than is one which increases only slowly in the spring. It is too often the case in regions where this disease is prevalent that the nectar flows are not so correlated with the period of initial expansion as to result in a strong enough population to enable a colony to overcome the presence of this disease. That strength of population will minimize the effects of diseases of adult bees also is shown by the comparatively slight loss occasioned by *Nosema apis* in strong colonies. Morgenthaler (*12*) has stated his belief that a good prolific queen is one of the greatest aids in overcoming the Isle of Wight disease. In other words, the colony which successfully withstands the disease must be in good condition and strong enough to discount the loss in the adult population. Among all the invaders of hive or colony itself, the wax moth furnishes probably the most commonly recognized example of the importance and utility of a strong colony population as a curb to the harmful activities of invading organisms. For a colony to be strong throughout an entire season, however, a maximum increase in population must have been made first of all during the initial expansion. The successful beekeeper supplies conditions which cause the largest possible increase of colony population during the initial expansion, not only for the sake of obtaining a large number of honey gatherers during this period, but also to provide sufficient bees to resist chance inroads upon the colony. This especially applies in regions where natural conditions between the period of initial expansion and the main honey flow are not conducive to a sufficient increase in population to keep the colony from falling an easy prey to certain invading organisms.

Among some of the important factors which are within the power of the beekeeper to provide are a prolific queen, sufficient bees wintered over to meet all brood-rearing requirements in the spring, sufficient worker brood cells, sufficient stores of good honey, and proper insulation. All of these are factors which must and can be provided in the manipulations in the latter part of the previous season if the beekeeper wishes to take the utmost advantage of the natural tendency toward intense brood-rearing activity at the beginning of spring. Conditions within the hive making for brood rearing during the period of initial expansion may be likened to a charge of explosives set to go off at a certain moment in the spring, the time

depending on weather conditions; in the one case the force of the resulting explosion is definitely predetermined by the quantity of the charge; in the other case the amount of brood reared is definitely predetermined by the provisions made in the preceding season to give the colony the conditions most favorable for this purpose.

THE MAJOR PERIOD

The major period of brood-rearing activity extends throughout the active season from the time when normally the initial seasonal tendency would cease to make itself felt until the beginning of the period of final contraction. It is the longest of the three phases of seasonal activity. The character and sequence of honey flows under different climatic conditions cause brood-rearing activity during this phase to vary widely in different regions. Throughout the world, on the whole, brood-rearing activity during the major period falls either into one of two extreme types or into a gradation between the two. During this period one of the extreme types is marked by a continuous high rate of brood-rearing activity, while the other extreme type is marked by a pronounced slackening or series of slackenings in such activity. In the third or intermediate type there is neither a continuous high rate of brood-rearing activity during the major period, nor under normal conditions is there at any time a complete suspension. This intermediate type, however, does show a seasonal slackening at some time within the major period.

A continuous high rate of brood-rearing activity during the major period occurs in regions with a long inactive season in winter, followed by a short active season, usually characterized by overlapping honey flows. Following the prolonged period of winter suspension in such a region, brood-rearing activity during the period of initial expansion attains with striking rapidity a high rate, which, unless checked by conditions within the hive, is maintained throughout the major period extending over practically the whole of a relatively short active season and then, owing to the proximity of the period of winter suspension, undergoes an abrupt contraction. Such a type of seasonal brood-rearing activity during the major period is typical of subarctic conditions.

A more or less complete suspension of brood rearing, or series of such suspensions, is found in regions with a short, almost nonexistent, inactive season, followed by a long season of activity, usually characterized by one or more periods of drought during the hottest weather. In such a region the initial expansion in brood rearing does not progress so rapidly as in regions with a long, inactive winter season, nor is the final contraction so abrupt. The major period, instead of being characterized by a uniformly continued high rate of brood-rearing activity, is characterized by a pronounced midsummer slackening, or series of slackenings, in brood-rearing activity, probably caused by an absence of incoming nectar and pollen during the periods of drought. This type of brood-rearing activity during the major period is typical of tropical conditions.

Intermediate between the two types just described is that type of seasonal brood-rearing activity which exhibits a more or less marked slackening at some time during the major period, but never a complete suspension under normal conditions. This type may be found

in the middle and southern latitudes of the United States. Brood-rearing activity after this period of midseason slackening may equal in intensity and extent that which took place before the slackening. An example of this type is found in regions of the southern Appalachian Mountains, where there is an early honey flow from the tulip-tree, followed by a midsummer dearth of nectar, which in turn is succeeded by a later honey flow from sourwood. In other regions where the continuity of brood-rearing activity is broken by a midsummer dearth of nectar brood rearing during that portion of the major period having the larger amount of nectar available is much more active than it is in the other portion. In the vicinity of Washington, for example, brood rearing is much more actively carried on before this midsummer dearth than afterwards. The main honey flow from tulip tree comes early, and the only later nectar flow of any consequence comes in September, and it often happens that even this yields little surplus. In the typical buckwheat region of the United States conditions are reversed in that the main nectar flow comes after a period of decreased brood-rearing activity in the middle of the major period.

Certain regions, which otherwise, because of lack of nectar from natural sources, would show a tendency toward a midseason slackening of brood rearing, have had this tendency overcome through other agencies, such as the production of honeydew in midseason or by the introduction of plants which secrete nectar under conditions or at times when the native plants do not. This has happened in the southeastern part of the United States through the introduction of cotton and sweet clover. Such circumstances tend to cause brood rearing to remain at a higher level during certain portions of the major period than normally would be the case.

Although the maximum nectar-gathering activity of the season takes place in the major period, the amount of surplus stored is really determined to a large measure during the major period of the preceding season. This is true because the amount of surplus obtained during any season depends on the number of field bees available during nectar flows, and the number of field bees, in turn, depends largely on brood-rearing activity during the initial seasonal expansion. Granting a prolific queen, an abundance of worker cells, sufficient stores, and proper insulation at the beginning of the initial expansion, however, the amount of brood reared during that period will depend largely on the number of bees reared during the latter part of the preceding major period and which have wintered over. It follows, then, that one of the most important aspects of the major period lies in the fact that during it the conditions arise which will lead to success or failure in the honey crop of the next year, so far as the activity of the colony itself is concerned. Most of these conditions are under the control of the beekeeper, and consequently may be provided by him at the proper time. In this same period the beekeeper must also guard against swarming. During the major period, moreover, surplus honey may be consumed needlessly by the colonies instead of being stored, if the colonies did not reach their maximum field strength for the season until after the honey flow was over.

During the initial expansion there is a tendency for all colonies to increase brood-rearing activity regardless of conditions; during the final phase there is an irresistible tendency for all colonies to contract

brood rearing, but only during the major period do colonies exhibit such diverse characteristics in brood rearing as to indicate a response during this phase to conditions which serve to counteract a normal seasonal tendency. It therefore follows that during the major period the beekeeper by his manipulations can best modify the behavior of a colony in the direction which he most desires.

PERIOD OF FINAL CONTRACTION

The period of final contraction represents a continuous decrease in brood rearing during the end of the active season, until by the beginning of the inactive season brood rearing has ceased entirely. A contraction of brood rearing is a normal occurrence before the winter suspension, and is purely a seasonal phenomenon. The decrease may be abrupt, dropping from a high rate of activity to zero in a remarkably short time, as happens in regions characterized by short, active seasons with overlapping honey flows. In regions where there is scarcely any incoming nectar during the latter part of the active season, the final contraction may not be pronounced in its last stages. In short, the rapidity of this decrease is dependent upon the proximity of the last honey flow to the period marked normally by a complete suspension of brood-rearing activities. The greater the quantity of sealed brood in the hive when the seasonal contraction begins and the nearer in time this beginning is to normal seasonal suspension, the greater are the chances for successfully passing through the inactive season, because such a condition in any colony means that it will enter the winter period with far more young bees than will one in which the final seasonal contraction is gradual and covers a relatively long time.

SEASONAL SUSPENSION

In the period of seasonal suspension a complete cessation of all brood-rearing activities takes place in a normal colony which is wintering well. Any brood rearing which occurs during this period is out of season, being abnormal and the result of some harmful factor, such as poor stores, an insufficient number of bees, insufficient insulation, or some outside disturbance of the colony itself. The length of the period of seasonal suspension varies greatly, according to the length of the winter. To bring his colonies through this period successfully is one of the most important problems of the beekeeper, in warm as well as in cold climates. As a matter of fact the problem is often more acute in regions with short inactive seasons than it is elsewhere, not only because there are more flight days but also because there is a less abrupt break from a high level of brood-rearing activity at the end of the previous season, so that colonies under such conditions will have fewer bees at the beginning of the inactive season. Although the large number of flight days is an advantage in connection with the more frequent possession of a poorer grade of honey stores in such localities, it is a disadvantage in view of the fact that useless flights throughout the inactive season rapidly deplete the population of a colony which entered the period of suspension of brood rearing under less favorable circumstances than normally is the case in regions with short active seasons.

DESCRIPTION OF THE COLONIES USED IN 1921

The brood-rearing investigation in 1921, as originally planned, was to be carried out along lines which would tend to show the effects of insulation, of stores, and of the age of the queen. Accordingly, each of the 16 colonies used in 1921 had been wintered in two 10-frame Langstroth hive bodies, eight colonies having been left all winter without packing and eight having been wintered in quadruple packing cases. The colonies were not in any way manipulated for the purpose of changing their brood-rearing rate, except that the addition of frames or supers had some influence in this respect. The record is, therefore, largely a presentation of what bees do without the interference of the beekeeper. The colonies without packing comprised two groups of four, and it was the original intention that the packed colonies should comprise the colonies in two packing cases. Since, however, one of the packed colonies became queenless during the winter, a colony packed in another group was used in its place. The group containing three colonies was unpacked on March 8, while the substituted colony (No. 10) was unpacked on March 21; but the group containing four colonies was not unpacked until May 5. Three of the colonies without packing had queens bred in 1919, whereas all the others, including both those with and without packing, had 1920 queens. Lack of stores was not during 1921 a factor in the brood-rearing activity of the eight unprotected colonies, as each colony proved to have more than sufficient stores for all purposes. Of the colonies packed all winter, four had heavy stores of honey, whereas the other four had light stores, all in the second hive body. The early spring was so favorable for incoming nectar and pollen, however, that each colony except No. 15 had sufficient stores for spring brood-rearing purposes. All the 16 colonies used were located at the Bee Culture Laboratory, Bureau of Entomology, at Somerset, Md., near Washington, D. C.

In an endeavor to determine some of the factors which influence brood-rearing activity during the three phases of the active season, it is of interest to study the seasonal brood records of these 16 individual colonies. For this purpose the general features of the brood-rearing activity in 1921 of 15 colonies are presented here, as well as a somewhat more detailed study of the brood record of an additional colony for two successive seasons. For each of these colonies a seasonal curve (figs. 1 to 16) has been constructed, based on counts (Tables 1 to 16) of sealed brood made from photographic records taken in 1921, as well as an additional curve (fig. 17) for one of these colonies, based on data (Table 17) from 1922. Although at first glance the 17 curves seem to show little correlation, they reveal definite relationships on closer study. The apparent differences result from abnormal conditions within individual colonies, which caused modifications in the brood-rearing responses. On the whole, the 17 curves point to certain more or less definite and constant seasonal variations in brood-rearing activity, due to normal, seasonal stimuli, but subject to modifications by the presence of any abnormal factors. This fact becomes apparent upon an examination of the two successive seasonal curves presented for colony No. 4.

It may be noted in passing that, even before unpacking colonies wintered in two hive bodies in quadruple packing cases, removal of frames from the lower hive bodies can be accomplished readily by

the following method: Before packing, three frames in the lower hive body are replaced by two chaff division boards the lugs of which have been sawed off. After removing the frames in the second hive body these division boards in the lower hive body can be pulled out easily, and the space created by their removal is then sufficient to allow removal of the frames which were there with them. The space occupied by two packed division boards of the type commonly manufactured is equivalent to that occupied by three Langstroth frames.

SEASONAL CHARACTERISTICS OF 1921

In the season of 1921 the weather conditions at the location of the bureau apiary were not favorable for a maximum honey crop. Although warm weather in late February and the fore part of March had brought out fruit bloom and other flowers somewhat prematurely, and although the thermometer registered as high as 90° F. (32.22° C.) on March 27 and 28, on March 29 and 30 most of this early bloom was destroyed by frost. On the morning of April 1, moreover, traces of snow were visible on the covers of the hives. During the fortnight beginning March 29, with one exception, when 59° F. (15° C.) was the minimum registered, the temperature dropped each night well below the clustering point (57° F., 13.89° C.) even reaching the freezing point on six occasions. One 96-hour period had a maximum of only 62° F. (16.67° C.) and a minimum of 29° F. (−1.67° C.). On four occasions 57° F. (13.89° C.) was the highest temperature recorded during a 24-hour period. Slight precipitation occurred on eight days of this fortnight. Such weather curtailed pollen and nectar gathering, which had just before been going on very actively.

Warmer weather set in again with the middle of April, and continued until the end of the summer, although there were a few days of cold, rainy weather in early May. The temperature during April ranged from 29° F. (−1.67° C.) to 96° F. (35.56° C.); in May, from 39° F. (3.89° C.) to 93° F. (33.89° C.). Rain on six consecutive days, beginning with May 11, spoiled the chances for a large yield from black locust (*Robinia pseudacacia*). On May 18 the tuliptree (*Liriodendron tulipifera*) began to yield nectar, but a four days' rain beginning May 23 put an end to nectar from this source. Nectar was available in small quantities from other sources during the latter half of April and throughout May.

During practically the whole of June much honeydew, as well as pollen, was available, and for a short time after June 15 a slight amount of nectar from basswood (*Tilia* spp.) and sweet clover (*Melilotus alba*) was collected. During July little nectar came in, although during the week beginning July 15 a small quantity of pollen was brought into the hive. Beginning August 3, and throughout the rest of the month, pollen was carried into the hives in large quantities, and it was fairly abundant during September. Beginning September 12 and continuing until the end of that month a small nectar flow from various Compositae was on. October proved to be a period of little activity as far as pollen or nectar gathering was concerned.

BROOD REARING OF A TYPICAL COLONY FOR TWO SUCCESSIVE SEASONS

Of the 16 colonies used in 1921 the seasonal brood-rearing record of one (No. 4) during 1921 and 1922 has been chosen as normal and as typical of the whole group. This colony stored the most surplus honey during the two successive seasons and its seasonal brood-rearing curves for the two years are strikingly similar, taking into consideration certain minor differences due primarily to weather conditions. During the winter preceding each of the two seasons this colony was left without packing in two 10-frame Langstroth hive bodies with abundant stores of honey. Nothing additional was done to stimulate brood rearing in the course of the two years except to furnish an abundance of room at all times, the queen having free access to all hive bodies. In 1921 the first super, or third hive body, was given to the colony on April 26, whereas in 1922 the first super was given on April 14. In both seasons the queen still had plenty of room in the original two hive bodies at the time the third hive body was given. Other supers were given later, so that in 1921 the colony had a maximum number of five hive bodies, and in 1922 a maximum of six. Owing to the policy adopted of providing an abundance of room at all times, not only for incoming nectar but for the egg-laying activity of the queen as well, the total number of hive bodies furnished during each season provided one hive body in excess of the actual minimum requirements of the colony. No added hive bodies were removed until October in either year; in 1921 the number was reduced to two on October 11, and in 1922 the same was done on October 16. Although there was no restriction to any possible expansion of the brood area, on no occasion was brood found above the lower three hive bodies. The same queen was used throughout both seasons, having been introduced into the colony in late summer in 1920 as soon as she had commenced to lay. For purposes of identification her left wing was clipped in July, 1921. In brief, each spring found this colony with a fairly strong force of bees, a prolific queen, combs composed chiefly of worker cells, and no shortage of honey stores.

INITIAL EXPANSION, COLONY NO. 4

In each of the two years of this experiment, as shown by observations, the chief source of nectar, tuliptree, was yielding freely by May 21. For these years, then, the maximum amount of sealed brood should have been attained during the last week in April, but in neither 1921 nor 1922 did the maximum brood-rearing correspond with ideal conditions. (Figs. 4 and 17 and Tables 4 and 17.)

In 1922 the maximum amount of sealed brood was reached during the first week in May, whereas in 1921 this maximum was not attained until about two weeks later, although a more auspicious beginning had been made occasioned by the unusually early spring. Nectar and pollen came in abundantly throughout March, but the secretion of nectar and the production of pollen were affected adversely by the inclement weather at the end of March and beginning of April, and probably the lower temperatures also affected unfavorably the activity of the unpacked colony. The adverse conditions finally checked the initial seasonal expansion of the brood, as is shown by a decrease in the amount of sealed brood in the latter half of April,

1921. A recovery in the rate of brood rearing was made subsequently, but at a time when factors associated normally with the major period were making themselves felt. It follows that the maximum amount of brood rearing in 1921 was not purely the result of the initial seasonal tendency.

In 1922, on the other hand, there was a late spring, inclement weather in early March causing a temporary shortage of pollen in the hive. These conditions restricted somewhat the initial seasonal tendency, as is clearly evidenced in the brood curve for that month. In spite of this beginning, April weather proved so favorable that by the end of the month the principal sources of nectar were as far advanced as in the previous year, and brood-rearing activity became so pronounced that the maximum for the season was practically reached before factors peculiar to the major period became dominant. In fact, the maximum in sealed brood in 1922 was attained in advance of the tuliptree honey flow, and about two weeks in advance of that of the previous year.

THE MAJOR PERIOD, COLONY NO. 4

In 1922, the more typical year, the beginning of the major phase was marked by a maintenance of brood rearing at the highest rate of the year (fig. 17). Since the maximum had been attained just before the locust bloom, the high rate was kept up for a couple of weeks. During the week of maximum sealed brood, brood rearing was undoubtedly still being carried on under the impulse of the intitial tendency, but influencing factors characteristic of the major period were also becoming evident. The week of the maximum marked the point of division between the initial seasonal tendency and the major period. Nectar subsequently coming in from the tuliptree tended to restrict the queen, and after this honey flow there was a dearth of nectar until the middle of September. During June, however, there was an appreciable amount of incoming pollen, and in August there was an intense pollen yield. As a consequence the decline in brood-rearing activity which set in with the beginning of the tuliptree honey flow and extended until the intense pollen yield in August was broken by a slight increase in June, in response to the pollen yield. The increase in August, on the other hand, was very pronounced. This was followed by a decrease until incoming nectar, chiefly from goldenrod, made itself felt by another slight increase in the brood area.

In the main, brood-rearing activity during the major period of 1921 was very similar to that for 1922. In the month of June, 1921, the increase in brood rearing was more pronounced, for two reasons. In the first place, instead of a gradual decline following the peak, as in 1922, a sharp decrease occurred in 1921. This happened because just prior to the honey flow the queen had ascended to the third hive body to lay, there being already at that time an extensive brood area in this hive body. Incoming nectar, however, so quickly cut down the number of cells available for the queen as to force her soon to return to the second hive body. Here, too, so many available cells within the brood area proper had been filled with nectar during her absence that the total number of cells made empty either by emerging bees or by consumption of stores did not suffice during that week to permit keeping up her former rate. During the next two

weeks, with the emergence of many bees in both the second and third hive bodies, the queen had more room and was able to approach a rate comparable to that attained in the same period of the following year. In the second place, there was an exceptionally large quantity of honeydew available, associated with incoming pollen during June, and also a certain amount of nectar from sweet clover. Throughout this month the queen had all the room needed for a normal response to these stimuli. In both seasons, after July 1, the brood curves follow parallel courses during the remainder of the major periods. At the end of July in each season brood-rearing activity had been reduced to approximately one-half that represented by the maximum of the same year.

FINAL CONTRACTION, COLONY NO. 4

In each year the final seasonal contraction in brood-rearing activity took place almost entirely in October, covering only three weeks in 1921 and four weeks in 1922. The abruptness of the contraction in these few weeks is shown from the fact that in the last week of September there were practically half as many cells of sealed brood as were found in the maximum counts for the respective years. As a result, the colony entered each following season strong in bees.

The brood-rearing record of this colony, although not ideal, is the most satisfactory of any of the 16 colonies because the maximum brood rearing bears some correlation to the initial expansion. The portion of the major period immediately following the period of main nectar secretion is not marked by a disproportionate degree of brood-rearing activity. In the late stages of the major period, moreover, there is an increase in brood rearing, providing a sufficient number of newly emerged bees at the beginning of the final contraction to insure successful wintering and an auspicious beginning of the next active season. That conditions within the colony remained nearly constant during the two consecutive years is indicated by the striking similarity in the curves of brood-rearing activity during both active seasons. (Fig. 18.) At the beginning of the experiment this colony was fairly strong; and, although it was subjected to no special manipulations except to have plenty of room and stores available at all times, it was fully as strong in bees at the beginning of the seasonal suspension in the fall of 1922 as it was in early spring in 1921. The performance of this colony, therefore, leads to the conclusion that, other conditions being equal, a strong colony tends to remain strong.

GENERAL OBSERVATIONS ON THE REMAINING COLONIES

Having given the record for colony No. 4 in some detail for the two seasons, it is not necessary to discuss so minutely the records of the remaining colonies observed during the season of 1921. Only the outstanding points regarding the various colonies will be considered. Unless otherwise stated, all colonies lived through the winter of 1921–22.

Colony No. 1 had been wintered without packing but was provided with an abundance of stores and had a 1920 queen. The brood-rearing activity of this colony furnishes a good example of the response of a mediocre queen to such a combination of factors as sufficient stores, sufficient worker bees, and sufficient brood cells at the

beginning of the active season. During the initial expansion a rate of brood rearing was reached almost equivalent to that at the height of the whole season. In fact, the amount of sealed brood (fig. 1 and Table 1) indicates no striking fluctuations in the rate of brood rearing during the three months when this was most active. Even the continued addition of many young bees to the population of the colony during this time failed to heighten the brood-rearing activity. The cold weather of April, the nectar flow of May, the honeydew and pollen yield of June, the pollen of August, and the nectar flow of September, may all be traced by the variations in the quantity of sealed brood. The response to the stimulus in August was only slight. In relation to the number of bees reared during the major period, the initial expansion was not nearly enough pronounced, nor did the final contraction represent a large enough break in brood-rearing activity to insure successful wintering. This colony died during the winter of 1921–22, leaving only a small quantity of stores in the hive.

Colony No. 2 also had a 1920 queen, plenty of stores, and had been wintered without packing. Although this queen was more prolific than the queen in colony No. 1, as is shown clearly by the curves of sealed brood for these colonies (figs. 1 and 2, Tables 1 and 2), there were not sufficient bees in the colony at the beginning of the active season to cause the maximum brood rearing to be correlated closely with the initial expansion. The maximum was reached only in June, after the population of the colony had increased sufficiently over that obtaining during the initial expansion to take care of an enlarged brood area. This rate was reached coincidently with the honeydew yield in June. As the incoming honeydew was placed within the brood area, restricting the number of cells available to the queen, an abrupt decrease in brood rearing followed in the week immediately after the maximum. A partial recovery in the rate of brood rearing occurred along with a relatively small pollen yield in July, after which, with one exception, brood-rearing activity decreased continuously until the September nectar flow. This exception took place during the pollen yield of August, as is shown by the fact that at this time the curve remained at about the same level for one week. The brood-rearing activity of this colony shows the same responses to weather and incoming pollen and nectar as have been noted for colonies 1 and 4, there being, of course, differences in degree. The maximum brood-rearing activity of the season came after the major period was well advanced, and is consequently too much out of proportion to the initial expansion to represent ideal conditions.

Colony No. 3 was wintered without packing, had been given heavy stores, and had a 1919 queen. This queen had enough bees at the beginning of the active season to support her maximum egg-laying activity, as is shown by the fact that scarcely any more sealed brood was found in the hive on any occasion in May than had been found during the initial expansion in March and April. (Fig. 3 and Table 3.) Because the queen was old and about worn out, incoming nectar in May soon severely restricted her activity, the result being a marked drop in the brood rearing for that month. At the beginning of May she had been crowded out of the second hive body, in which she had been laying almost exclusively, into the lower hive body. Even there

the brood area was quickly hedged about by incoming nectar, with the consequent great reduction in cells available for egg laying. Emerging bees made more room available in June; and consequently, under the stimuli of incoming pollen and honeydew, the queen's activities were increased to a limited extent. After this there was a continuous decrease in brood rearing until the old queen was superseded in August. The colony had been endeavoring to supersede her since May, but all queen cells had been removed as soon as found. Finally one was left intentionally, from which a virgin emerged. The colony had become rather weak by August, however, and the curve shows no apparent response to the pollen yield of that month, although the old queen was still alive. The new queen had mated and had commenced to lay by August 25. During the nectar flow of September she attained a rate which compared favorably with that attained by the old queen even during the initial expansion. Owing to the fact that the old queen was failing, the brood-rearing responses of this colony to nectar and pollen yields are not so clearly shown as in colonies with more vigorous queens. The effect of the April weather is, however, very apparent.

Colony No. 5 (fig. 5 and Table 5) was wintered without packing, had a 1920 queen, and was provided with abundant stores of honey. In fact, the second hive body was so well filled with honey that the queen was cramped for room in late March, and it was deemed advisable to replace two frames of honey in the second hive body with empty frames. Although before these empty frames were substituted the queen had reached the limit of room for egg laying in the second hive body, scarcely any brood was reared in the lower hive body until May or June, even though plenty of room was available there in March. Before the cold spell in April there were more than sufficient bees in the hive to take care of brood in all available cells in the second hive body, but not enough to maintain in addition a large brood area in the lower hive body. The addition of the two extra frames permitted an expansion of the brood area in the second hive body, and the amount of sealed brood mounted slowly, even during the cold weather. During this period, however, the queen laid no eggs in the lower hive body.

In her activities the queen kept pace with the ever-increasing number of young bees from the first part of April until the maximum of the season. During this period, nevertheless, brood-rearing activity suffered a slight check in May, at a time when much pollen and some nectar were coming in. No super had as yet been given the colony, and, as much of the pollen and nectar were being deposited within the brood nest proper, the queen was once more cramped for room. A super given at this time relieved the shortage of room and furnished storage space for what little surplus was gathered during the tuliptree nectar flow immediately following, and more particularly during the honeydew yield of June, when the maximum brood-rearing activity of the season was attained. During the dearth of nectar immediately afterwards, brood-rearing activity fell off noticeably until stimulated by the pollen yield in August. From the height of the response to this stimulation until the beginning of the September nectar flow, brood-rearing activity underwent another striking decrease. There was somewhat of an increase in September, which, although rather conspicuous on the curve, was not nearly great

enough to insure the best wintering conditions. The greatly diminished brood-rearing activity during the latter part of the major period must be attributed to a failing queen, because at any time after July, except for that drawback, there were sufficient bees, stores, and room to have resulted in a much greater amount of brood during August and September.

Seasonal brood-rearing activity of the type represented by this colony is anything but satisfactory from the standpoint of obtaining a honey surplus. Owing to lack of room, the initial expansion did not have a chance to proceed normally, even though sufficient bees to meet the queen's egg-laying capacity were not on hand. As a result of having its early development arrested and retarded, the initial expansion became merged with the major period. Owing to lack of sufficient bees, brood-rearing activity increased with relative slowness, even after sufficient room had been provided. As a consequence, the maximum of sealed brood was not attained until too late for the resulting bees to be useful in gathering nectar for surplus. Comparatively slight brood-rearing activity at and preceding the final contraction spelled danger to the colony in the coming winter, and well illustrates the evil results of failure to requeen at the proper time. This colony died in the winter of 1921–22, with some honey still remaining in the hive.

Colony No. 6 (fig. 6 and Table 6) had a 1920 queen, stores in abundance, and had been wintered without packing. For this colony, there is no sharp distinction between initial expansion and major period. Colony No. 6 had an overabundance of stores in the second hive body in early spring, thus restricting the queen; but it did not have enough bees to permit expansion of the brood area downward into the lower hive body at the rate at which it was begun in the second hive body. There occurred, therefore, a slight diminution of the brood area at the end of March, but the colony so increased in population during the fore part of April as to provide more than enough bees to take care of brood in all the cells available. Brood-rearing activity consequently increased to the maximum in late May, excepting another slight break in April, caused by weather conditions. Following the maximum there was a rather abrupt decrease due to the presence of fresh nectar temporarily within the brood nest. A super added during the last week of May partially provided room for the honeydew in June, and thus tended to eliminate further restriction of the brood area. In fact, an increase in brood rearing took place in June. Although the queen had reached in May her maximum for the year, she was able to make a noticeable increase in her rate, even in July, after having dropped off from her maximum for June. It may be added that some pollen was coming in at this time. A decrease then followed which lasted until September. Possibly owing to the July increase, the response to the pollen yield of August is apparent only as a slight diminution in the rate of decrease. However, a pronounced increase in brood rearing took place during the September nectar flow. The initial expansion of the colony is merged too completely with the major period. During the major period there was too much brood rearing, resulting in a useless consumption of stores.

Colony No. 7 (fig. 7 and Table 7) had a 1919 queen and sufficient stores and had been wintered without packing. Sufficient bees were

in the colony at the beginning of the initial expansion to have supported a greater rate of brood rearing than was attained. Sufficient cells were also available, but the queen was evidently too old to have made any better showing than she actually did. Her maximum was reached during the initial expansion. A rate nearly equal to the maximum was maintained for about a month, and then a decline set in which reduced brood-rearing activity to practically zero by the end of August. At that time the old queen was superseded. The brood-rearing activity of the new queen, even in September, equaled that of the old queen during the initial expansion. The fact that this colony at the beginning of the active season did not have a queen prolific enough to allow it to carry on brood rearing at a rate consistent with its strength in bees, available brood cells, and honey stores, accounts for the fact that it does not exhibit all of the responses to seasonal phenomena found in the other colonies.

Colony No. 8 (fig. 8 and Table 8) also had a 1919 queen, had been without packing all winter, and had plenty of stores. This colony had the poorest queen of any of the 16 colonies used. During the initial expansion she attained almost her maximum rate for the season. The cold weather in April caused a slight decrease, but her maximum was reached in early May. Incoming nectar in that month restricted her activity and a decline followed. On August 18 the colony was queenless. A virgin queen emerged during the next week but never mated. Finally on September 8 a young queen was introduced which began to lay on September 15, but was lost two weeks later, after having made a good start. Another queen was introduced successfully in October, but too late to produce much brood.

Colony No. 9 was unpacked on March 8, had sufficient stores and a 1920 queen. The curve of sealed brood for this colony (fig. 9 and Table 9) is typical of a queen which lays at her maximum rate during the season, the rate being fairly uniform during most of the major period. As this was a packed colony, only seven frames were in the lower hive body. The three frames completing the normal number were not added until the last week in March, and the colony became somewhat crowded for room, thus restricting the queen during the period of initial expansion. The added combs helped to relieve the brood area proper from further restriction by pollen, with possibly a little nectar. The fact that the queen was utilizing only the second hive body at the time of the inclement weather in April, coupled with the fact that there were more than sufficient bees on hand to allow an expansion of the brood area even at this time, resulted in an increase of brood rearing during April until the maximum of the season was reached at the end of the month. From that time until late August, when this queen was naturally superseded, brood was reared at a fairly uniform but generally decreasing rate. Although an excess of room was provided, so that this queen was restricted in no respect, there were but slight reactions to the nectar of May and the pollen and honeydew of June. Supersedure interfered with the response to the pollen yield of August, although there are indications that the response had already begun before the new queen emerged. She was laying by the beginning of September. The increase in brood rearing during that month was due probably not only to the incoming nectar but to the presence of a young queen as well. Criticism of the

seasonal brood-rearing activity of this colony may be put in two ways. It may be said either that brood rearing during the initial expansion did not sufficiently exceed that maintained during the larger part of the major period, or that brood-rearing activity during the larger part of the major period was continued too nearly at the same rate as during the initial expansion, thus causing too large a consumption of stores in the hive in rearing brood uselesssly and in feeding an idle population.

Colony No. 10 (fig. 10 and Table 10) began the season under ideal conditions as far as the queen herself was concerned, and was unpacked March 21. The original queen had been introduced in 1920, had plenty of bees, room, and stores, and consequently attained her maximum rate of brood rearing during the period of initial expansion. The weather apparently had little effect on the activity of this queen; the decline from the maximum of the season is rather gradual and the subsequent increase is made slowly. The colony had plenty of room, but the nectar in May received a relatively slight response. The queen was not seriously restricted by incoming nectar, and probably was laying at her maximum capacity. A further slight response was brought about by honeydew in June. In July, however, the queen was lost and brood rearing dropped off abruptly. A virgin queen was reared which mated and began laying in August. This queen soon reached the limit of empty brood cells, as the brood nest had become rather well filled with pollen and some nectar. Two empty frames were therefore placed in the second hive body, which were promptly used by the queen. As a result of this additional room the queen had all the cells necessary during the remainder of the season. The initial expansion of the season was timely enough, but it was not sufficiently greater in activity than was brood rearing during June and July to spell success in surplus. The final contraction presents fairly satisfactory conditions.

Colony No. 11 (fig. 11 and Table 11) afforded the best illustration of any of the 16 colonies of what may be accomplished during the initial seasonal expansion if conditions within the hive are favorable. This colony had a 1920 queen, was unpacked on March 8, and had no more stores than were sufficient to meet brood-rearing requirements before early nectar began coming in; a condition which gave the queen a maximum amount of room. Besides these factors, there were at the beginning of the active season plenty of bees and a prolific queen. Under the spur of the tendency toward the initial expansion, the brood area increased with great rapidity. At the time of the change in weather conditions in April, the brood area had been expanded so far that a further expansion was not possible and a break occurred. A recovery was soon made which culminated in May, when incoming nectar caused another restriction of the brood area. During June a short-lived recovery was made which was terminated by a decrease, probably due in part to a restriction of the brood area by honeydew, but more likely to the absence of any great stimulus toward increased brood-rearing activities during July. Even so, the queen continued active enough to respond in a small degree to the minor pollen yield in July. Owing to the large number of field bees on hand in August, the brood area was so restricted by the quantities of pollen brought in that the queen was unable to make much of a response. In fact, a rapid decrease followed

this pollen yield, and continued until the fall nectar flow. Increased brood-rearing activity under this new stimulus was slight in comparison with that under stimuli earlier in the season. Notwithstanding the fine example of an optimum initial expansion represented by this colony, brood rearing was a little too active in proportion in May, and especially so in June, and exhausted uselessly what little nectar had been gathered in May.

Colony No. 12 had a queen which attained her maximum capacity during the initial expansion. This colony was unpacked March 8, had a 1920 queen and stores just sufficient, leaving plenty of room available for brood rearing. The April decline, characteristic of so many of the other colonies, appears to have been for the most part avoided in this colony, probably because of the presence of a large number of bees. Although April weather may have prematurely ended the initial expansion, the fact that, excepting one sporadic occasion, the quantity of sealed brood did not at any time equal the quantity found at the height of the initial expansion, tends to show that the queen was laying throughout at about her maximum capacity. The curve of sealed brood (fig. 12 and Table 12) shows a decrease in early May, followed by an increase later in the month which may be correlated with the tuliptree nectar flow. The increase, however, did not bring brood rearing up to the maximum attained during the period of initial expansion. A decrease followed the May increase; but it was checked in part by the incoming honeydew and pollen, after which there was a sporadic upshoot at the very end of this period. From that time on there was a marked, rapid decrease in brood rearing until the queen was superseded in August. The new queen was laying on August 16 and quickly attained a relatively high rank in September, but unfortunately was lost in that month. A new queen emerged and mated but did not begin to lay until October 4, too late to make much of a showing. The two peaks in the curve, following the maximum of the initial expansion, disturb the proportions of an ideal curve; but the bees reared during these two increases in the brood-rearing rate doubtless enabled the first new queen to establish the good record to her credit.

Colony No. 13 (fig. 13 and Table 13) was unpacked on May 5 and had a 1920 queen and more than sufficient stores. At the time of the bad weather in April practically all available cells were in use either for stores or for brood, the lack of available brood cells accounting largely for the April decline shown. A super was added on April 29 which, with three frames placed in the lower hive body instead of the packed division boards, provided plenty of room. Brood rearing then so increased that the maximum of sealed brood was reached the second week in June. In May incoming nectar interfered slightly with brood rearing just prior to the maximum, and honeydew caused a further restriction just after the maximum. The rate then became stable for a few weeks until the queen disappeared. A virgin was reared naturally which mated and began to lay on August 19. Brood-rearing activity was carried on at a fairly rapid rate, but suffered a slight check just prior to the September nectar flow, incoming pollen causing a restriction in room. The peak attained in September was sufficiently high to insure plenty of bees for winter. As the maximum brood-rearing activity came in the major period after the main honey flow was over, there was no occasion to expect a large honey crop in 1921.

Colony No. 14 (fig. 14 and Table 14) had neither sufficient bees nor sufficient room to allow the queen to lay eggs at her maximum rate during the initial expansion. This colony had a 1920 queen and an abundance of stores. The large quantity of stores, both in the upper and the lower hive bodies, reduced the area available for brood rearing to less than the requirement of the colony. This condition was rendered more acute by the fact that until the time of unpacking, May 5, there were only seven frames in the lower hive body. The effect of lack of room is visible in the brood curve at the end of March. At this time, to give more room, a frame in the second hive body was replaced by an empty brood frame, with the result that there was a slight increase in brood rearing. This extra space was not sufficient, however, for the incoming pollen and nectar and for the brood. A decline in April resulted from this factor and from any influence of the weather. A super was added in the last week in April, shortly before the colony was unpacked. This relieved the congestion, and in May the brood rearing rose well above the height attained during the initial expansion. That the maximum was not attained until June is evidence of the fact that there were not sufficient bees in the hive from the latter part of April, when an abundance of room became available. After June came the normal seasonal decrease in brood rearing, lasting until pollen in August produced a rather long-continued response. Following this another decrease occurred until goldenrod nectar made itself felt. Owing to a large number of field bees the brood nest became much hemmed in. The brood-rearing record of this colony was entirely unsatisfactory from the standpoint of the honey producer, because the height of brood rearing came after all chance of storing surplus was past, and was so pronounced that to maintain the colony's new population meant serious inroads on what nectar had been gathered.

Colony No. 15 (fig. 15 and Table 15) was unpacked on May 5, had a 1920 queen, light stores, and not sufficient bees to allow brood-rearing activity to keep pace with the egg-laying activity of the queen. This was the only one of the four packed colonies (Nos. 11, 12, 15 and 16) provided with light stores which showed any diminution in brood rearing directly traceable to lack of honey stores. When observations on this colony were first made in March, 1921, the honey stores were found to be low. Not being so strong in bees as the other colonies just mentioned, it was not able to gather so much nectar during March, and therefore had to use proportionately more reserve stores in that month. The records of sealed brood reveal a check to the brood-rearing rate in late March, followed by an increase. The fact that this increase took place within two weeks after giving the colony a full comb of honey in the lower hive body is an evident indication that, at the time the extra comb of honey was given, there was neither sufficient honey in the hive nor sufficient nectar coming in to support any great increase in brood-rearing activity. The increase was only short lived, because at the time of the cold spell in April the brood area had become as large as could be covered by the bees in the hive during such weather. The queen was necessarily restricted to this area for the time being, and as a large part of the brood in it remained sealed for several days she did not have sufficient cells available for further egg laying. The emergence of young bees, however, gave her a chance to refill the cells in this

area, as is shown by a rise in the curve during the first week of May. In the meantime, however, the upper edges of this area had been cut off by incoming nectar and pollen. Field bees had been kept busy during the latter part of April after the cold weather, although nectar was not very abundant. To relieve the resulting congestion, a super had been given in the last week of April, about a week before unpacking, and on unpacking three more frames had been placed in the lower hive body to take the place of the packed division boards. With this extra room the queen was able to expand the brood area in proportion to the number of nurse bees. The result was a sharp rise in May to a maximum which was maintained throughout most of June. During this period there was plenty of room in the hive to provide cells for the activities both of the field bees and of the queen. From the latter part of June until the pollen yield of August the activities of the queen became more and more restricted, excepting a brief response to pollen in July. A fair response was made to the pollen yield of August. By this time the large number of bees which had emerged during June, plus the brood reared after that month, had depleted the honey stores to a point which caused a serious diminution of brood-rearing activity between the pollen yield of August and the nectar flow of September. In the spring the colony had not suffered from want of stores but had no great surplus; during the May nectar flow and the greater portion of the honeydew yield in June sufficient field bees had not as yet developed to add much to the surplus stores. Consequently during the summer practically all of the honey stores were consumed. To save the colony it became necessary to add three full combs of honey to the second hive body in the second week in September. This factor, coupled with the oncoming nectar flow, caused another increase in brood rearing. By the second week in October honey stores were practically depleted once more, and it was necessary to add more frames of honey. Under such circumstances brood rearing had not progressed actively enough just prior to the seasonal contraction to afford this colony an optimum number of bees for winter. The whole curve is highly unsatisfactory, because the initial expansion does not represent sufficient brood-rearing activity and because too wide a gap separates the maximum activity of the major period from the initial expansion. At the end of the season there is also too wide a gap in the continuity of the curve for the major period between the point of demarcation of the seasonal contraction and the next preceding high point of the major period.

Colony No. 16 had a 1920 queen, light stores, and was unpacked on May 5. Although the brood curve for this colony (fig. 16 and Table 16) shows a rather rapid and early initial expansion, there were not quite enough bees for the queen. During the initial expansion the queen was utilizing all of the 10 frames in the second hive body. She had reached the limit of the area of brood which could be cared for in March, however, and a slight decrease followed. With the emergence of young bees more room was available within the brood area, and the queen began to take advantage of this, but was restrained somewhat by the cold weather in April. When the warm weather came, before the queen could take possession of all the cells made available by emerging bees, a large number of cells had already been used for incoming nectar and pollen, resulting in a striking drop

in the curve. As a matter of fact, at one time the queen was confined to one side of the brood area by a comb filled almost entirely with fresh nectar. More room was given by the addition of a super during the last week in April. Unpacking on May 5 meant the addition of three frames in the lower hive body to replace the packed division boards. As a result, both of the extra room and of the stimulation of the May nectar flow, brood-rearing activity expanded back to the level attained in March. Incoming nectar occasioned a slight decrease during the latter part of May, but feeding of larvæ on hand soon removed this restriction. The maximum of the season was attained in June, but soon gave way to a sharp decrease brought about by incoming honeydew. A partial recovery was made, which in turn was stopped by another decrease because the brood area had been so restricted by honeydew that few empty cells were to be found. More room was available within the brood area proper at the time of the small pollen yield in July, which resulted in an increase followed by a decrease. Loss of the queen at this time then caused a suspension of brood rearing. A virgin was reared, which mated and began laying before the September honey flow. As in the case of colony No. 15, there is too wide a gap between the initial expansion and the main activity of the major period, and also too much of a break in the continuity of brood rearing just prior to the final contraction for this colony to have had the proper population during the various phases of the active season.

GENERAL DISCUSSION OF THE RECORDS FOR 1921

The brood-rearing records of these colonies show the region about Washington to be one in which seasonal brood-rearing activity tends toward slackening during the major period. The main brood rearing of the season comes before the occurrence of this tendency; but, following it, brood-rearing activity increases in normal colonies sufficiently to provide an adequate number of bees for winter.

INFLUENCE OF POLLEN AND NECTAR

Throughout the season direct responses were made to incoming pollen and nectar. The main nectar flows of the year come during the forepart of the active season, which is also normally the time of greatest brood-rearing activity. During July scarcely any fresh nectar is found, and brood-rearing activity is greatly diminished. In September there is a nectar flow, and associated with it is heightened brood-rearing activity. The correlation between a good pollen yield and brood rearing is well illustrated by the expansion of the brood areas during the pollen yield of August. That there will even be a response at times to a light pollen yield is shown by the colonies (Nos. 2, 6, 11, 15, and 16) whose brood-rearing activity did not decrease continuously throughout July. For the most part, owing to abnormal circumstances, conditions within these colonies did not become conducive to maximum brood-rearing activity until just before the period of nectar dearth; as a result, only a slight stimulus was needed to create a response in such colonies. That definite brood-rearing responses will be made from year to year to certain constant seasonal stimuli, other conditions remaining equal, is well brought out by the brood records of colony No. 4 for 1921 and 1922.

46969°—25†—Bull. 1349——4

CONDITIONS WITHIN THE HIVE

The value of insulation in early spring is not demonstrated clearly in the case of these colonies because virtually summer weather prevailed in March, thus producing conditions within the colonies which tended to offset in a measure any evil effects of the cold weather in early April. Unfortunately, too, the colonies (Nos. 13, 14, 15, and 16) which were left packed until May suffered from lack of room just at the time of the unfavorable weather, so that no comparison may be made with them. Of the colonies left all winter without packing four (Nos. 5, 6, 7, and 8) present such abnormal conditions due both to lack of room and to failing queens as to offer little light on this subject. The other four colonies, which were not packed for winter, however, did not suffer from lack of room, and, although each differed as to prolificness of queen and colony population, each shows a break in brood rearing associated with the cold weather of the fore part of April. Colony No. 4, nevertheless, had sufficient bees to overcome quickly the effect of this weather and to proceed to the maximum brood-rearing activity of the year. Although the brood-rearing activity of three of the colonies (Nos. 9, 10, and 12) unpacked in March appeared to be somewhat restricted during early April, the later performance of the queens in these colonies and the fact that no great decrease in brood-rearing activity immediately took place, indicate that sufficient bees were on hand to keep up the temperature of the brood area in its entire extent at that time, and even to have cared for a larger area had the queen been capable of increased egg laying. The brood area of the other colony (No. 11) which was unpacked in March shows a decided restriction following the cold weather. Although a comparison of the direct effect of adequate insulation on brood rearing can not be made from the brood records of these colonies in 1921, the fact remains that the colonies minus packing which were most normal did suffer a setback in brood rearing as a result of the cold weather. A strong colony without packing, like No. 4, shows, however, a certain amount of resistance to the effects of such weather.

CONDITIONS OF THE COLONY

The influence on brood rearing of the three important factors, prolificness of queen, colony population, and brood cells available, becomes so interwoven in certain colonies that it is hard to trace the separate influence of each. The important part played by colony population in determining when the maximum brood-rearing activity of the season will take place is well illustrated by colony No. 2, which reached the maximum of the brood-rearing season relatively late. In this colony lack of population was beginning to restrict the brood area somewhat, even in late March. Population of colony accomplishes little in itself if the queen is not prolific. The brood records of colonies Nos. 3, 7, and 8 all attest this fact. It so happened that each of these queens had been introduced two seasons previously. On the other hand, the queen of colony No. 4, in 1922, the second season after her introduction, made as good a record as in 1921. This shows that in certain instances, at least, the value of a queen can not be determined merely by her age.

STORES

As already stated, none of the 16 colonies suffered from lack of stores at the beginning of the period of initial expansion. No data were obtained, therefore, showing the effect of want of stores on brood rearing. It was evident, however, as soon as nectar became prematurely available from fruit bloom, that certain colonies had such an abundance of stores as to result in lack of room for any expansion of the brood area. The history of colony No. 14 brings out this fact, although in this instance colony population also influenced the result. The importance of having sufficient stores in early spring until incoming nectar supplies the current needs of the colony, and the need of room sufficient to offer no check to the initial expansion, should emphasize to users of the Langstroth or other hive bodies of equivalent size the value of wintering a colony in two hive bodies, and show that otherwise a full population for the honey flow is liable not to be attained.

OBSERVATIONS IN 1920

It has been thought of interest to introduce at this point the work done by Lloyd R. Watson in 1920, while he was connected with the Bee Culture Laboratory. As already stated, through direct counts of all eggs, larvæ, and sealed brood, he was able to obtain in that year a total of five seasonal brood records. (Tables 18 to 22.) It must be borne in mind that the curves (figs. 19 to 23) based on these records represent a total of all eggs, larvæ, and sealed brood, whereas the curves (figs. 1 to 18) based on photographic records made by the writer represent sealed brood only. Furthermore, the curves for 1920 are not drawn to the same scale as are the other curves in this paper. These differences in themselves would be sufficient to cause the curves to present apparent discrepancies in the time and degree of response even to the same stimuli. Unfortunately, too few data on each colony are available, other than the actual counts of brood, to warrant a close correlation between the brood records for 1920 and those already discussed. Nevertheless, the results for 1920 are in line with those presented for the succeeding years.

Each of the five colonies (A, B, C, D, and E) had been wintered in two hive bodies in quadruple packing cases. Colonies C, D, and E were unpacked on March 17, while colonies A and B were left packed until April 13. In August, 1919, a young queen had been introduced into each colony. All the colonies were well provided with stores.

In 1920, as in 1921, there was a period of cool weather during early April. From April 4 to April 11, inclusive, the minimum and maximum temperature corresponded roughly with the freezing point (32° F., 0° C.) and the clustering point (57° F., 13.89° C.) respectively. In fact, with two exceptions, the minimum temperature on each day of this period was below 32° F. (0° C.) whereas on only two occasions does the temperature record for any day within this period show a maximum of over 57° F. (13.89° C.). The two exceptions to the minimum are April 4, with a minimum record of 39° F. (3.89° C.), and April 5, with a minimum record of 43° F. (6.11° C.). The two exceptions to the maximum occurred on April 9 and April 11, the former having a maximum of 61° F. (16.11° C.), the latter of 64° F. (17.78° C.). The data available as to honey flows show that the most nectar of the year was gathered during the last half of May.

In 1920, contrary to conditions in 1921 and 1922, the nectar flow from black locust occurred during the last week in May, thus coming after the tulip-tree nectar flow, instead of before. June also furnished either nectar or honeydew, and a slight amount of nectar was available in September. No data are available as to pollen yields.

In the case of each colony, brood rearing in the spring of 1920 was begun first in the second hive body. A check to brood rearing took place during the cold weather of April in both the packed and unpacked colonies. Inasmuch as the method of direct counting necessitated keeping the frames out of the hive for a considerable time, thus creating a disturbance to the colony lasting over several hours, much brood must have suffered undue exposure, a fact which in itself would account for any check at this time, even though other data are not available. In colony E this check is not so evident, owing to natural requeening during this period. In May, in each case, before the maximum was reached incoming nectar gave a check to brood rearing, while the brood nest was being maintained in the second hive body only, sufficient bees not being on hand to engage in brood-rearing activity in the lower hive body. Consumption of this fresh nectar soon made more room available in the second hive body, and the continued emergence of bees so enlarged the colony population that possession was taken of the lower hive body for brood-rearing purposes. Only one super was given to any colony, this being provided on May 21. In each colony the maximum brood-rearing activity of the season was reached shortly afterwards. During the last week in August no records were taken, a fact which accounts for the gaps in the curves at that time.

Colony A (fig. 19 and Table 18), after the initial check to brood expansion in April, proceeded at a fairly rapid rate to its maximum. This was not attained until after the close of the tuliptree nectar flow. A rapid decline then ensued, lasting through June, probably first brought on by incoming nectar, but later accentuated by the fact that the queen was confined to the lower hive body by a queen excluder from June 9 to June 30. She was given the freedom of both hive bodies during the first two weeks of July, and a slight increase in brood-rearing activity took place. The dearth of nectar and pollen during the remainder of July brought on a further decline. On August 11 the super was removed. A slight increase in the brood-rearing rate was made in September at the time of the usual fall nectar flow. The queen was lost during the first week of October. A virgin queen was then reared and mated successfully, but too late to produce much brood before winter. The maximum brood rearing in this colony took place about a month too late for ideal conditions, and brood rearing just before the period of final contraction was not sufficiently great to afford an ideal number of young bees for winter.

Colony B (fig. 20 and Table 19), after the checks of April and May, attained its maximum in early June, following which there was a slight decline due to incoming nectar. A recovery made in the latter part of the month was followed by the midseasonal decline. On July 9 the queen was confined to the lower hive body, and on August 12 the super was removed. A somewhat pronounced response was made to the fall nectar flow.

Colony C (fig. 21 and Table 20) did less in brood rearing than any of the other colonies. The maximum rate was reached late in May. The midseasonal decline is not so sharp as in the case of the other

colonies; in fact, a rate nearly equal to the maximum was maintained throughout June. On July 19 the queen was confined to the lower hive body. Little response was made to the fall nectar flow. The brood-rearing activity of this colony did not augur well either for surplus or strength for winter.

Colony D (fig. 22 and Table 21) is the only other of the 1920 colonies comparable to colony A. It underwent the checks to brood rearing in April and May before reaching its maximum at the beginning of June. Colony A had reared more brood during this time than had colony D. Brood rearing in colony D, as in colony A, suffered a decrease immediately after the maximum. On July 7 the queen was confined to the lower hive body, was allowed the freedom of the second hive body on July 13, but was again confined to the lower hive body on July 20. Throughout the remainder of the season the brood nest was in the lower hive body. On August 10 the super was removed. During the last week of August the old queen was superseded. The combination of a new queen and the fall nectar flow caused a rather large increase in brood-rearing activity during September.

Colony E (fig. 23 and Table 22) lost its queen in early spring and a laying queen was introduced, the result being a condition somewhat equivalent to an early spring supersedure. The giving of a laying queen undoubtedly made the break in continuity of brood rearing shorter than would have resulted had it been necessary to wait for the mating of a virgin queen so early in the year. Even so, the colony did not reach its maximum brood-rearing activity until the second week in June. A decline ensued, the sharpness of which indicates a restriction due to incoming nectar. A rather slight recovery was made during the last week of June, followed in turn by a sharp decline. On July 2 the queen was confined to the lower hive body; was given access to the second hive body again on July 10, but on July 16 was confined to the lower hive body once more, where she remained for the rest of the season. On August 13 the super was removed. This colony made little response to the fall nectar flow.

In none of the five colonies did the initial expansion proceed without a check. The maximum brood-rearing activity of the season was reached too late to be of greatest value during the main honey flow, which, in the vicinity of Washington, D. C., usually occurs in May. With the possible exception of colonies B and C, in none of the colonies did brood rearing become so active just prior to the final contraction as to insure the number of young bees needed for good wintering conditions. As in the curves for 1921 (figs. 1 to 16), so in the curves for 1920 (figs. 19 to 23) there is shown a tendency for brood-rearing activity in the vicinity of Washington to reach its maximum during the fore part of the active season; this is succeeded in turn by a midseasonal decline broken more or less by incoming pollen or nectar. This decline is usually checked somewhat during the latter part of the active season by an abundant pollen yield in August and a nectar flow in September. Thus, barring differences due to variation in seasons, strength of colonies, and certain other factors within the hives which would cause in different colonies a variation in the responses even to identical stimuli during the same year, the general character of brood-rearing activity in the colonies under observation in 1920 is strikingly similar to that of brood-rearing activity in the colonies under observation in 1921 and 1922.

MIGRATIONS OF THE QUEEN WITHIN THE HIVE

Besides the study of brood-rearing activity in the colony as a whole throughout the year, it is of interest to follow the brood-rearing activity of the same colony within particular hive bodies during that period, because, if adequate room is provided, one hive body is rarely the scene of the brood rearing of a normal colony throughout an entire season. The existence of such a piece of apiary apparatus as a queen excluder suggests how common an occurrence it is for the queen to transfer her egg-laying activity from one hive body to another. The causes of these vertical migrations and the ultimate effects on brood-rearing activity are as yet not fully determined. In passing, another type of migration should be noted, which takes place entirely within a hive body and which may be termed a horizontal migration, or a migration from frame to frame. A knowledge of the causes and effects of the queen's migrations is of direct value in the determination of the size of frame and hive which will most directly contribute to a maximum brood-rearing activity.

Since, all things considered, colony No. 4 was the most normal of the 16, the migrations of its queen in 1921 (Fig. 24) and 1922 (Fig. 25) will be considered somewhat at length. The cluster of this colony during the winter preceding each of the two active seasons was located in the second hive body. It is probably because of this fact that brood rearing began there each spring. During the initial expansion of each year, however, the queen approached the limit of cells available in the second hive body, whereupon the lower hive body afforded the only room for an enlargement of the brood area, because the first super had not then been added.

In 1921, the season with inclement weather in April, there was comparatively little brood-rearing activity in the first hive body at any time. Such weather tends to contract the area occupied by the bees, and thus restrict the expansion of the brood area. These conditions, prevailing at the time of the queen's first visit to the lower hive body, naturally caused her stay there to be rather brief. When the weather became better more room was already available in the second hive body, owing in part to a further consumption of stores. This additional space allowed the queen to increase her egg-laying activities without much enlargement of the brood area in the first hive body which resulted from her initial visit. Furthermore, almost immediately afterwards, in May, nectar began to come in rather abundantly and was deposited in the third hive body, which had now been put on, the presence of nectar in this super attracting the queen upward rather than downward. In the meantime the first hive body became well filled with pollen and nectar. It is interesting to note that in the latter part of April, in response to the inclement weather, the sealed brood curve for the second hive body (Fig. 24) remains near a certain level until the effects of the bad weather have ceased, and that in the first hive body this curve does not rise above the point marking its first appearance. In 1922 (Fig. 25) the inclement weather occurred before the colony was in need of expanding into the lower hive body. The queen was therefore able to complete her stay below, and the sealed brood area in the first hive body came to occupy nearly as many cells at the end of April as had the brood area in the second hive body at the time of the expansion into the first.

The appearance of nectar in quantity in the third hive body is marked by migrations of the queen back and forth between the second and third hive bodies, her activity in the first dwindling away completely. In both seasons, by the beginning of the tulip-tree nectar flow the queen was at work in the third hive body, undoubtedly having been drawn there by the presence of large numbers of bees and incoming nectar, as well as having found so many cells in the other hive bodies filled either with brood, nectar, or pollen. On each return to the second hive body she found deposited there much pollen and some nectar. Each season these migrations produced three clearly defined peaks of brood rearing in the third hive body. Owing to the fact that between these peaks nectar was being crowded as closely as possible around the brood area, even in the cells from which bees had emerged, the queen was restricted continuously in room for egg laying. As a result, each successive peak in the third hive body became smaller and in the end no eggs were to be found above the second.

With the advent of the period of lessened brood-rearing activity in July, there was little incentive in either year for the queen to wander out of the second hive body. During the same period much of the honey and pollen in this hive body was consumed, with the result that at the beginning of increased brood-rearing activity during the latter part of the major period, caused by incoming pollen, there was sufficient room for a much larger expansion of the brood nest within this hive body than would be apt to take place at that time of year. This condition continued until the fall nectar flow, when the lateness of the season and possibly the slowness of the honey flow caused all incoming nectar to be deposited in the second hive body, around the outer edge of the brood nest or within it. The brood nest was then rapidly constricted by the moving of honey towards the center of the second hive body from both the first and third.

Since in none of the other colonies were conditions such as to induce vertical migrations to such an extent as in colony No. 4, general conclusions are not in order at this time. When all space in the second hive body became filled with brood or stores, the queen in colony No. 4 went below because there was no other place to go, and the population of the colony was already sufficiently great to be using the lower hive body. As the season progressed and a super was added and occupied the queen went up into the third hive body also, where there were so many bees and so much fresh nectar. At no time did she show signs of deserting the second hive body; and, when forced out of the third hive body by nectar and kept out of the first hive body by pollen and nectar, she confined her activity to the second hive body for the remainder of the season.

Although vertical migrations in brood-rearing activity were not carried to so extreme a degree by the other colonies as by colony No. 4, migrations did occur between the first and second hive bodies. In the case of the other colonies whose maximum brood-rearing activity came later in the season, consumption of stores had made more room available in the second hive body at the time of the need for the maximum room than was the case with colony No. 4, which needed room early. There was therefore not the need for expanding the brood area into another hive body to such a degree as in colony No. 4. Without exception, however, each colony did maintain more

or less of a brood area in the lower hive body during some portion of the season, and, in addition, colony No. 11 even made some use of the third hive body. In certain instances where much room was available in the second hive body horizontal migrations were found to exist. Whether vertical or horizontal, the peaks of brood rearing represented by these migrations are separated roughly by 3-week intervals, or the time necessary for brood to develop.

Statements to the effect that the queen hesitates to cross from one hive body to another are often found in the literature of beekeeping. As far as colony No. 4 (figs. 24 and 25) is concerned, there is no indication of any such hesitancy. It may be well to remember in this connection that Langstroth hive bodies were used in the experiment and that good worker combs were present. The curves at no point suggest that any of the breaks are due to a hesitancy in the transference of egg-laying activity from one hive body to another; in fact, the sharpest rise in colony No. 4 during 1922 is accompanied by such a transfer with no resulting break. This holds true of other parts of the curve for the same colony in 1922 as well as 1921. It would seem, then, that the queen will readily ascend or descend from one hive body to another if the intenseness of brood-rearing activity necessitates more room, provided worker bees have taken possession of the other hive body either because of activities in connection with nectar gathering or because of an overflow population.

COMPACTNESS OF BROOD NEST

In spite of any migration of the queen within the hive, a study of the location of the sealed brood (figs. 26, 27, 28, and 29) throughout the active season shows a remarkable compactness in the brood area. At all times of the season, except at about the time of the final contraction, the brood area of colony No. 4 occupied contiguous frames in the second hive body. The most apparent exception occurred during the final contraction in 1921, when the brood area in the second hive body became divided by combs which were filled entirely with honey. The same compactness is observable in the areas occupied in the first and third hive bodies, the only noteworthy exception being in 1922. In that year one of the frames in the third hive body became completely filled with nectar before the queen had occupied the frame on either side. When the brood area had included the frame next to this frame of honey, the queen passed around the full comb and laid eggs in the frame on the other side. For several weeks the brood area in the third hive body was thus divided. Whenever the brood area crossed the limits of the second hive body into the first and third, this expansion took place almost entirely in territory as adjacent as possible to the second hive body. This is not apparent from the figures, because for each side of any frame the bar represents by its length the size of the sealed brood area in proportion to the total surface of each side of that frame, represented by the vertical dimension of the frame, and not the exact location of the sealed brood on that frame. Hence the sealed brood in each frame is represented diagrammatically as being in the center of that frame. In the figures only sealed brood is represented, while the present discussion refers to the compactness of all brood.

The location of the sealed brood through both years brings out also the persistency of the brood area. By persistency of the brood area is meant a tendency to rear brood in the cells which have already been occupied by brood, and a tendency for any expansion in the brood area to take place only in cells on frames immediately adjacent to those already thus occupied. In each spring the area of sealed brood was expanded rapidly, but during any expansion the area first used for brood rearing was kept occupied for that purpose. The rapid increase in the number of cells on each frame occupied by brood is just as striking as is the increase in the number of frames used. The first relinquishment of any part of the brood area for any purpose other than brood rearing was due to encroaching nectar. Throughout both years the second hive body maintained its predominance as the center of brood-rearing activity, even though at times the queen carried on extensive egg-laying activity in the other hive bodies.

TIME RELATION OF BROOD REARING TO NECTAR GATHERED

It was pointed out at the beginning of this bulletin that the honey crop may be reduced (1) by an insufficient number of worker bees, (2) by a consumption of surplus honey by bees reared out of season, or (3) by swarming induced by a congestion of bees in the brood nest. Because colony No. 4 stored more honey than any of the other 15, and because its brood-rearing activity during 1921 presented features more ideal for the region of Washington than did the others, only this colony will be discussed in detail from the standpoint of the time relation of brood rearing to nectar gathered.

Although in 1921 the maximum of sealed brood in colony No. 4 came in conjunction with the height of the honey flow, the honey gathered during the main honey flow was not wastefully consumed by bees emerging later in the season, as the maximum field force was available to take advantage of an intense yield of honeydew. The maintenance for this large force during the summer was therefore provided through the efforts of the colony itself. In the season of 1922, although the actual maximum of sealed brood came a week late and a rate of emerging bees nearly equal to the maximum was maintained during part of the honey flow, the maximum rate had been nearly reached during the week prior to the peak. A creditable showing was therefore made, three supers being actually used for storing nectar, as stated earlier, whereas in 1921 one less super was given for this purpose.

A swarming impulse was scarcely noticeable during either 1921 or 1922 in any of the colonies under observation. A few queen cells were started; following the prompt removal of these no further preparations for swarming were observed. In none of the colonies, however, was the queen allowed to be so restricted in egg laying at any one time as to result in any significant reduction in the actual number of young bees needed to care for larvæ or perform other hive duties. This point is of importance because the presence of an overabundance of young bees has been held one cause of swarming. Demuth (*7, p. 13*) has stated: "The fact that the tendency to swarm is greatest at about the time the bees are rearing the greatest amount of brood has led to the belief that swarming is caused by the presence in the hive of a large proportion of young bees not yet old enough for field work." But, since under normal conditions bees not of field age perform duties inside the hive, it would seem that the mere

presence of bees too young for field work does not in itself induce swarming unless there is such an excess of young bees beyond those required for hive duties as to interfere with the routine of the colony.

Any appreciable excess of young bees arises, not for the sake of intensifying the natural swarming impulse, but rather as a result of other factors. Such an excess is bound to occur if conditions within the colony prevent a large number of young bees from performing the functions of their normal life cycle. This would be the case whenever brood-rearing activity reached the limit of cells available at a period when the brood-rearing area would have been further enlarged if more cells had been at hand, or if under similar conditions brood rearing were restricted through a reduction in the number of cells available for brood by their use for incoming nectar or pollen. The egg-laying rate being then reduced to a noticeable extent for several days, there would eventually be fewer larvæ to care for, fewer cells to clean out, fewer cells to be sealed over, and a diminution in all of the activities incident to a period of intense brood rearing. In consequence, since such duties are usually performed by young bees, there would be many of the latter out of a job, so to speak.

Throughout the observations in this research it has been noted that all colonies, strong as well as weak, tend to crowd incoming nectar not only around the border of the brood nest but even within the brood area itself whenever an empty cell is found. Such a tendency has long been recognized. Consequently, if during a honey flow many cells within the brood area proper become available for depositing incoming nectar through the emergence of large numbers of young bees, the queen may be restricted suddenly in her activity, as happened in 1921 to the queen in colony No. 4. Under these conditions there would result an excess of young bees. Whether this excess would be large enough to induce swarming would depend on the degree and duration of restriction of the queen's activities. In the case of colony No. 4 and the others the restriction was never of long duration. It has often been observed that just prior to swarming the queen almost entirely ceases egg laying, so that all unsealed brood disappears. Such a condition is simply the natural result if any large number of brood cells have been used for another purpose. Not only may the number of cells available for egg laying become insufficient through diversion to use for incoming nectar and pollen, but even without any reduction in number by these causes there will be too few whenever brood rearing itself reaches the limit of cells available in the hive. During a period of normal seasonal increase in brood-rearing activity, idle field bees may at times cause a congestion within the hive which apparently interferes with brood rearing. Any of these conditions may arise independently of any honey flow, and would tend to explain the fact that swarming is not always correlated with a honey flow.

In the colonies under discussion a swarming impulse was doubtless restrained by the fact that at no time was any colony crowded for room long enough to cause a serious break in the continuity of brood rearing at a time when the tendency toward brood-rearing activity was strong. Whenever any queen became restricted in any particular hive body during a period favorable to continued, heightened brood-rearing activity, she was able to migrate to a more suitable region within the hive. Through this ability to transfer her activity else-

where the queen was able to maintain an egg-laying rate which was normal in its response to the varying stimuli of the season as modified by the condition of the colony itself. Thus in these colonies the possibility of the occurrence of such a large excess of idle young bees as would be conducive to swarming was reduced to a minimum, a fact which may account largely for the absence of any indication of a swarming impulse in either season.

EGG LAYING

From the counts of sealed brood (Tables 1 to 17), the maximum daily egg-laying average over a 12-day period has been calculated for each of these colonies, 12 days being the average time represented by sealed worker brood. Any daily average derived from sealed brood is not to be interpreted as representing the actual daily egg-laying performance of the queen bees in question, since it has long been recognized that a queen bee lays more eggs than ever develop into adults. This excess of eggs is often very evident in spring, becoming less apparent during maximum brood-rearing activity, and again becoming evident in the fall. The constant seasonal correlation found in the weekly counts of sealed brood throughout the years covered by this investigation shows, however, that a reliable index to seasonal brood-rearing activity may be obtained by counts of sealed brood. Since the success of brood-rearing activity is to be gauged by the number of adult bees reared, it is evident that this is more closely determined from counts of sealed brood than from any other type of brood count.

In neither season did the queen in colony No. 4 approach any such a daily egg-laying rate as that found by Von Berlepsch (*3*) in his experiment. The same holds true of the other 15 colonies studied in 1921. The highest daily average during any 12-day period, as derived from the counts of sealed brood, was found to be 1,587, and represents the performance of the queen in colony No. 4 in 1922, her highest similar rate in 1921 being 1,488. Of the other colonies in 1921, colony No. 14 had a maximum daily rate of 1,513. Five colonies (Nos. 2, 6, 11, 15, and 16) show maximum daily rates between 1,250 and 1,400, while the similar rates of six (Nos. 1, 5, 9, 10, 12 and 13) were between 1,000 and 1,250. In 1921 the maximum daily average of each of the 1919 queens is below 1,000. The time relations between maximum brood-rearing activity and nectar flows or pollen yields have already been discussed for each colony. The queen in colony No. 12, even in September, shortly after first beginning to lay, attained a daily average of 905.

In the colonies studied in 1920 an egg-laying rate of over 1,500 per day was attained in only one colony, the queen in colony A averaging 1,528 eggs per day for one 21-day period. In colony D, in the same year, the queen attained a maximum daily rate of 1,468 eggs for one 21-day period, and the maximum daily egg-laying rates of the queens in colonies E, B, and C for any 21-day period were 1,223, 1,201, and 1,008, respectively. These daily averages may be compared with Dufour's (*11*) maximum daily average of 1,627 during any 21-day period. On the other hand, Baldensperger (*1*), in his estimates already referred to, gives 2,600 as a daily average for a period of 23 days. It must be remembered, however, that Baldensperger's method is not adapted for strictly accurate scientific results. Of the

daily egg-laying rates found by Brünnich (*6*) even the highest is slightly below 2,000. In fact, he states his belief that a daily rate of 2,000 eggs has never been exceeded in any of his colonies.

At the end of his article already referred to, Dufour (*11*) makes a statement which applies with equal effect to the colonies used in this work. Although he recognizes that the egg-laying rates which he publishes are only averages and, as such were undoubtedly exceeded at times, he justly asserts that the results of his work do not warrant the assumption that any such daily egg-laying rates as 3,000 or more had ever been reached in any of the colonies used in his experiments. Since the daily egg-laying average for any season is far below the daily egg-laying average for any particular number of days within the maximum of that season, it is readily seen that the remarkably high rates of egg laying over short periods, so often published in beekeeping literature, can not be used as the daily averages for an entire season.

CONCLUSIONS

In this work no special effort has been made to modify the time of the various phases of brood rearing or to increase their intensity other than to provide adequate stores and ample room at most times; the colonies were therefore in much the same condition as might be found in an average apiary. The following conclusions may be drawn from the records of brood rearing presented here:

The number of bees in the colony at the beginning of brood rearing in the spring, the ability of the queen, the abundance of stores, the suitability of the combs and proper insulation are the most important factors within the control of the beekeeper which determine the amount of brood reared by a colony.

The seasonal brood cycle in any region is marked by certain definite phases—the initial expansion, the major period, and the final contraction. These tend to remain constant from year to year, their normal occurrence and magnitude being determined to a large degree by local weather conditions and by the local honey flows and pollen yields.

A strong colony tends to retain its strength from year to year, other things being equal.

A queen at times transfers her egg-laying activity from one hive body to another, without any appreciable diminution in her rate of egg-laying if the combs are good.

The possibility of young bees occurring to such an excess as to be conducive to swarming is reduced if the queen has ready access to another hive body, in case egg laying in the one already occupied becomes restricted through incoming pollen, nectar, or brood-rearing activity.

Every colony used in 1921 shows a migration of the queen from one hive body to another, from which it may be inferred that if only one hive body had been available the amount of brood reared would have been reduced.

There is a decided tendency for the brood area of the colony to be confined to adjacent combs in one or more hive bodies in such a way as to maintain the brood area in compact form.

Although it can not be concluded from this investigation that the use of old queens is always disastrous, the records show that their use is accompanied with risk.

Prolonged inclement weather retards brood rearing in the spring, although a strong colony may be able to maintain its rate through unfavorable cold weather of only a few days' duration, even though it is not packed.

During the latter part of the active season the beekeeper may make important preparations for the next year's honey crop by providing any of the factors which are necessary for the unrestricted increase of brood rearing during the period of initial expansion. Among the most important of these for every colony are good stores in sufficient quantity to last until incoming nectar suffices in the next active season, a good queen, and an abundance of worker comb. Although some of these conditions might be provided in the spring, any postponement is dangerous. Such preparations during the preceding active season, together with any others necessary for good wintering, may be expected to result in increased brood rearing so early in spring as to have the largest field force of the season available during the nectar flow instead of after it has passed.

LITERATURE CITED

(1) Baldensperger, Ph. J.
1895. How many eggs does a queen average per day during the year? *In* Gleanings Bee Cult., vol. 23, pp. 950–951.

(2) Baldridge, M. M.
1861. Fertility of the queen. *In* Amer. Bee Jour., vol. 1, pp. 109–110.

(3) Berlepsch, Baron August von.
1860. Die Biene und die Bienenzucht. 475 pp.

(4) Brünnich, Karl.
1912. Brutmessungen. *In* Schweiz. Bienen-Ztg., bd. 35, No. 7, pp. 257–261, 1 fig.

(5) ———
1919. Das Messen der Brutflächen im Bienenstocke. *In* Schweiz. Bienen-Ztg., n. F., bd. 42, Nos. 6, 8, pp. 225–227, 283–288, 2 figs.

(6) ———
1922. Graphische Darstellung der Legetätigkeit einer Bienenkönigin. *In* Arch. Bienenkunde, bd. 4, No. 4, pp. 137–147, 2 figs.

(7) Demuth, George S.
1921. Swarm control. U. S. Dept. of Agr., Farmers' Bul. 1198, 47 pp.

(8) Desborough, J. G.
1852. On the duration of life in the queen, drone, and worker of the honeybee; to which are added observations on the practical importance of this knowledge in deciding whether to preserve stocks or swarms; being the prize essay of the Entomological Society of London for 1852. *In* Trans. Ent. Soc. London, 2d ser., vol. 2, pp. 145–171.

(9) ———
1855. Observations on the honeybee, in continuation of the prize essay of the Entomological Society for the year 1852. *In* Trans. Ent. Soc. London, 2d ser., vol. 3, pp. 187–196.

(10) ———
1868. Observations on the duration of life in the honey bee. *In* Trans. Ent. Soc. London, 3d ser., vol. 6, pp. 225–230.

(11) Dufour, Léon.
1901. Recherches sur la ponte de la reine. *In* Annuaire de la Fédération des Sociétés Française d'Apiculture, 10me Session, pp. 18–34, 2 figs.

(12) Morgenthaler, Otto.
1923. Einiges über die Krankheiten der erwachsenen Bienen. *In* Schweiz. Bienen-Ztg., n. F., bd. 46, Nos. 1, 2, pp. 22–28, 81–85, 2 figs.

(13) Reaumur, Réné Antoine.
1740. Mémoires pour servir à l'Histoire des Insectes, vol. 5, Paris.

(14) Swammerdam, John.
1758. The book of nature, or the history of insects. (English trans. from the original Dutch and Latin editions. London.)

TABLES

TABLE 1.—*Record of sealed brood in colony No. 1 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 16	4,871	May 9	11,090	July 5	10,786	Aug. 29	5,484
21	7,858	16	11,601	11	10,134	Sept. 6	4,655
28	9,713	23	11,596	18	9,152	12	4,563
Apr. 4	10,100	31	12,322	25	7,319	19	4,012
11	11,260	June 6	11,256	Aug. 1	6,939	26	5,410
18	10,140	13	10,731	8	6,139	Oct. 3	4,485
25	9,500	20	10,970	15	5,898	10	1,772
May 2	10,412	27	11,148	22	6,175	17	401

TABLE 2.—*Record of sealed brood in colony No. 2 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 16	5,821	May 11	13,551	July 6	9,489	Aug. 31	6,543
23	11,438	18	13,178	13	9,853	Sept. 7	4,908
31	12,212	25	12,873	20	13,613	14	4,920
Apr. 6	13,366	June 1	13,352	27	11,849	21	7,196
13	13,067	8	14,068	Aug. 3	10,271	28	6,008
20	9,867	15	14,693	10	9,587	Oct. 5	2,156
27	10,822	22	15,399	17	7,649	12	569
May 4	12,814	29	15,787	24	7,591	19	473

TABLE 3.—*Record of sealed brood in colony No. 3 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 17	4,355	May 19	10,821	July 14	5,626	Sept. 8	1,098
25	8,795	26	4,711	21	5,013	15	5,843
31	10,414	June 2	3,184	28	4,432	22	9,582
Apr. 7	11,339	9	4,928	Aug. 4	3,272	29	4,940
14	9,736	16	6,297	11	2,214	Oct. 6	2,756
21	8,667	23	6,804	18	1,832	13	1,859
28	10,543	30	6,794	25	[1] 1,639	20	708
May 5	11,743	July 7	6,177	Sept. 1	1,472	26	365
13	11,614						

[1] Supersedure.

TABLE 4.—*Record of sealed brood in colony No. 4 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 16	5,012	May 10	16,982	July 5	13,659	Aug. 30	8,898
23	9,024	17	17,859	12	11,741	Sept. 6	9,448
29	11,186	24	17,155	19	11,084	13	8,015
Apr. 5	12,327	31	10,955	26	9,904	20	7,862
12	14,781	June 7	13,079	Aug. 2	8,204	27	9,433
19	15,402	14	12,408	9	7,840	Oct. 4	7,644
26	14,072	21	13,674	16	7,459	11	3,973
May 3	15,028	28	14,588	23	7,871	18	1,143

TABLE 5.—*Record of sealed brood in colony No. 5 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 18	4,187	May 11	8,134	July 6	11,502	Aug. 31	5,043
23	4,919	18	8,763	13	10,224	Sept. 7	1,640
30	3,949	25	11,047	20	8,669	14	2,121
Apr. 6	3,696	June 1	12,277	27	6,168	21	3,300
13	4,662	8	12,830	Aug. 3	4,571	28	3,652
20	4,940	15	12,567	10	3,803	Oct. 5	1,372
27	5,765	22	13,062	17	4,187	12	
May 6	8,949	29	12,405	24	7,267		

TABLE 6.—*Record of sealed brood in colony No. 6 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 18	5,702	May 9	14,829	July 5	13,313	Aug. 29	6,029
21	7,593	16	15,592	11	11,870	Sept. 6	4,856
28	9,415	23	16,211	18	12,679	12	6,686
Apr. 4	9,120	31	16,401	25	12,554	19	7,818
11	11,536	June 6	14,130	Aug. 1	11,048	26	7,871
18	12,976	13	11,893	8	9,369	Oct. 3	4,694
25	12,772	20	13,304	15	8,296	10	945
May 2	14,497	27	14,690	22	7,584		

TABLE 7.—*Record of sealed brood in colony No. 7 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 17	4,914	May 10	9,923	July 12	2,496	Sept. 13	9,769
22	8,308	17	10,319	19	2,015	20	10,849
29	10,332	24	9,232	26	1,253	27	5,888
Apr. 5	10,904	June 1	7,558	Aug. 2	996	Oct. 4	4,492
12	11,149	7	7,348	9	659	11	3,066
19	10,050	14	6,977	16	454	18	669
26	10,531	21	5,436	23	338		
May 3	10,887	28	3,650	30	[1] 127		
6	10,417	July 5	2,354	Sept. 6	2,873		

[1] Supersedure.

TABLE 8.—*Record of sealed brood in colony No. 8 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 16	4,241	May 19	8,768	July 21	6,411	Sept. 22	1,014
25	7,092	26	8,070	28	6,154	29	4,380
31	7,650	June 2	7,591	Aug. 4	5,856	Oct. 6	4,147
Apr. 7	8,504	9	7,669	11	5,390	13	[5] 1,152
14	8,542	16	6,402	18	5,614	20	([6])
21	7,623	23	6,338	25	[1] 2,685	26	520
28	8,091	30	6,711	Sept. 1	([2])	Nov. 3	2,075
May 5	8,825	July 7	6,410	8	([3])	10	1,136
14	9,088	14	6,507	15	([4])		

[1] Supersedure.
[2] Virgin lost.
[3] Requeened.
[4] New queen laying.
[5] Queenless, requeened.
[6] New queen laying.

TABLE 9.—*Record of sealed brood in colony No. 9 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 17	6,397	May 9	11,245	July 5	11,375	Aug. 29	[1] 8,274
21	8,337	16	11,421	11	10,789	Sept. 6	5,851
28	8,686	23	11,670	18	10,331	12	7,842
Apr. 4	8,443	31	11,638	25	10,199	19	9,004
11	10,297	June 6	11,408	Aug. 1	10,549	26	8,703
18	10,951	13	10,620	8	10,015	Oct. 3	5,831
25	11,536	20	10,744	15	9,854	10	2,350
May 2	12,223	27	11,521	22	9,961	17	197

[1] Supersedure.

TABLE 10.—*Record of sealed brood in colony No. 10 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 23	8,196	May 18	12,352	July 13	10,878	Sept. 7	6,936
31	10,218	25	12,119	20	9,645	14	6,603
Apr. 6	10,985	June 2	11,276	27	8,661	21	8,241
13	12,392	8	10,717	Aug. 3	4,191	28	8,675
21	12,886	15	11,294	10	(1)	Oct. 5	5,677
27	12,103	22	11,758	17		12	3,165
May 4	11,434	29	11,745	24	2,188	19	907
13	12,242	July 6	11,376	31	6,102	25	695

[1] Natural requeening.

TABLE 11.—*Record of sealed brood in colony No. 11 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 17	6,475	May 14	15,580	July 7	12,928	Sept. 1	7,281
25	12,283	19	15,414	14	11,840	8	4,388
31	13,788	26	16,227	21	10,847	15	5,294
Apr. 7	16,134	June 2	14,678	28	10,914	22	7,699
14	15,712	9	10,855	Aug. 4	10,658	29	7,804
21	12,837	16	14,916	11	9,406	Oct. 6	4,661
28	12,388	23	15,205	18	9,687	13	1,231
May 5	14,585	30	15,054	25	9,731		

TABLE 12.—*Record of sealed brood in colony No. 12 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 18	5,904	May 17	9,930	July 19	9,213	Sept. 20	5,557
22	7,417	24	11,651	26	8,289	27	(2)
29	9,328	June 1	12,095	Aug. 2	4,675	Oct. 4	
Apr. 5	11,017	7	11,156	9	2,768	11	316
12	12,913	14	10,276	16	2,042	18	657
19	13,229	21	10,335	23	1,202	26	497
26	12,855	28	10,500	30	[1] 372	Nov. 1	162
May 5	12,682	July 5	13,520	Sept. 6	5,295		
10	10,718	12	9,897	13	10,871		

[1] Supersedure. [2] Natural requeening.

TABLE 13.—*Record of sealed brood in colony No. 13 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 18	3,404	May 13	10,783	July 8	12,680	Sept. 2	8,564
25	6,728	20	12,684	15	11,681	9	8,313
Apr. 1	8,291	27	13,220	22	11,605	16	9,511
8	9,444	June 3	13,256	29	9,871	23	10,134
15	10,533	10	14,752	Aug. 5	4,648	30	6,891
22	9,724	17	12,234	12	[1]	Oct. 7	3,655
29	8,705	24	12,732	19	----------	14	1,431
May 6	9,768	July 1	12,745	26	4,141	21	379

[1] Natural requeening.

TABLE 14.—*Record of sealed brood in colony No. 14 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 18	9,101	May 13	12,018	July 8	16,098	Sept. 2	11,404
25	12,412	20	14,106	15	15,463	9	7,597
Apr. 1	11,732	27	16,479	22	14,281	16	7,404
8	12,856	June 3	17,175	29	11,889	23	9,436
15	12,527	10	17,414	Aug. 5	12,299	30	5,180
22	9,995	17	18,162	12	12,929	Oct. 7	1,757
29	9,545	24	18,151	19	13,126	14	963
May 6	12,012	July 1	16,779	26	13,446	21	192

TABLE 15.—*Record of sealed brood in colony No. 15 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 18	6,514	May 13	8,425	July 8	13,949	Sept. 2	6,976
25	8,225	20	12,957	15	12,017	9	2,489
Apr. 1	8,469	27	15,608	22	12,293	16	4,311
8	11,605	June 3	15,545	29	10,907	23	8,240
15	9,938	10	15,555	Aug. 5	8,969	30	2,929
22	7,794	17	15,625	12	7,846		
29	8,531	24	16,080	19	9,119		
May 6	11,214	July 1	15,239	26	10,467		

TABLE 16.—*Record of sealed brood in colony No. 16 during the season of 1921, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 18	6,654	May 13	8,719	July 8	12,686	Sept. 2	[1]
25	12,034	20	13,043	15	8,423	9	3,586
Apr. 1	13,778	27	13,974	22	10,485	16	8,555
8	12,259	June 3	12,914	29	8,914	23	6,304
15	12,949	10	14,383	Aug. 5	8,036	30	2,987
22	5,461	17	15,845	12	6,744	Oct. 7	1,701
29	3,632	24	13,397	19	3,449	14	131
May 6	6,009	July 1	11,115	26	48		

[1] Natural requeening.

TABLE 17.—*Record of sealed brood in colony No. 4 during the season of 1922, by weeks*

Date	Sealed cells	Date	Sealed cells	Date	Sealed cells	Date	Sealed cells
Mar. 10	3,190	May 12	18,694	July 14	10,494	Sept. 15	8,519
17	5,521	19	18,661	21	9,597	22	8,395
24	6,125	26	17,301	28	8,703	29	8,870
31	6,435	June 2	16,204	Aug. 4	8,321	Oct. 6	6,102
Apr. 7	9,831	9	14,457	11	8,523	13	3,756
14	14,372	16	13,658	18	8,872	20	2,986
21	17,096	23	14,154	25	10,177	27	1,183
28	18,755	30	13,942	Sept. 1	10,548		
May 5	19,049	July 7	12,614	8	9,649		

TABLE 18.—*Record of brood in colony A during the season of 1920, by weeks*

Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells
Mar. 15	2,842	May 26	32,092	Aug. 4	15,343	Oct. 13	[2]
22	3,206	June 2	30,466	11	14,472	20	2,065
29	7,748	9	28,530	18	14,253	27	3,493
Apr. 6	15,686	16	23,886	25	[1]	Nov. 3	3,519
14	11,101	24	20,611	Sept. 2	12,562	10	3,273
21	16,622	30	19,153	9	10,311	18	1,601
28	21,160	July 8	19,713	15	8,939	24	860
May 3	25,895	14	19,034	22	9,585		
12	30,421	21	18,347	29	6,489		
19	30,258	28	16,527	Oct. 6	3,340		

[1] No record taken. [2] Natural requeening.

TABLE 19.—*Record of brood in colony B during the season of 1920, by weeks*

Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells
Mar. 10	1,394	May 13	16,656	July 15	17,774	Sept. 16	9,000
15	1,338	20	19,683	22	17,799	23	10,703
22	1,542	27	24,370	29	16,358	30	12,341
29	5,060	June 3	25,231	Aug. 5	14,102	Oct. 7	6,986
Apr. 7	8,239	10	23,314	12	12,894	14	3,417
15	5,983	17	23,349	19	12,835	21	1,275
22	9,093	25	25,255	26	[1]	28	864
29	12,595	July 1	23,927	Sept. 3	10,452	Nov. 4	331
May 4	15,461	9	18,884	10	7,968		

[1] No record taken.

TABLE 20.—*Record of brood in colony C during the season of 1920, by weeks*

Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells
Mar. 17	2,609	May 17	18,051	July 19	16,873	Sept. 20	9,866
24	3,497	24	20,194	26	16,090	27	8,572
31	7,159	29	21,177	Aug. 2	15,422	Oct. 4	7,613
Apr. 7	8,261	June 7	19,536	9	15,428	11	4,394
13	8,692	14	19,150	16	16,446	18	1,995
19	8,655	22	18,678	23	[1]	25	824
26	12,024	28	19,346	31	14,031	Nov. 1	155
May 5	17,894	July 6	19,198	Sept. 7	10,525		
10	16,626	12	18,331	13	9,761		

[1] No record taken.

TABLE 21.—*Record of brood in colony D during the season of 1920, by weeks*

Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells
Mar. 17	3,397	May 18	23,382	July 20	20,910	Sept. 21	11,519
24	4,987	25	29,411	27	18,022	28	15,016
31	10,222	June 1	30,840	Aug. 3	19,347	Oct. 5	10,779
Apr. 7	13,374	8	29,059	10	18,631	12	6,976
13	11,466	15	28,019	17	19,189	19	4,650
20	12,564	23	26,556	24	(1)	26	3,223
27	18,691	29	26,431	Sept. 1	[2] 7,536	Nov. 2	633
May 6	24,788	July 7	21,777	8	3,234		
11	25,157	13	20,822	14	7,120		

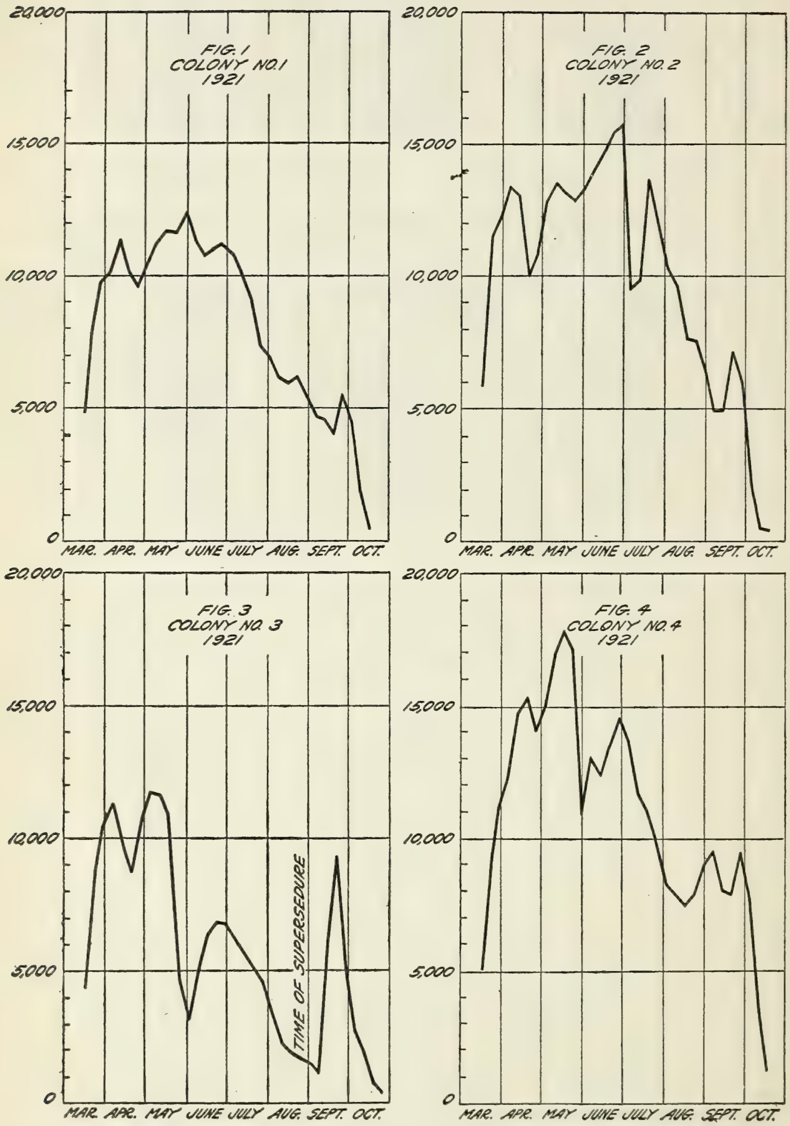
[1] No record taken. [2] Supersedure.

TABLE 22.—*Record of brood in colony E during the season of 1920, by weeks*

Date	Total o feggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells	Date	Total of eggs, larvæ, and sealed cells
Mar. 17	1,037	May 21	19,546	July 23	13,190	Sept. 24	8,384
24	1,567	28	22,398	30	10,686	Oct. 1	8,918
31	4,897	June 4	23,523	Aug. 6	11,809	8	6,182
Apr. 8	6,078	11	25,685	13	12,826	15	4,652
15	(1)	18	22,250	21	12,519	22	2,877
23	6,458	26	21,706	28	(2)	29	1,304
30	11,255	July 2	22,469	Sept. 4	12,251		
May 7	14,821	10	22,077	11	9,330		
14	15,537	16	18,077	17	8,426		

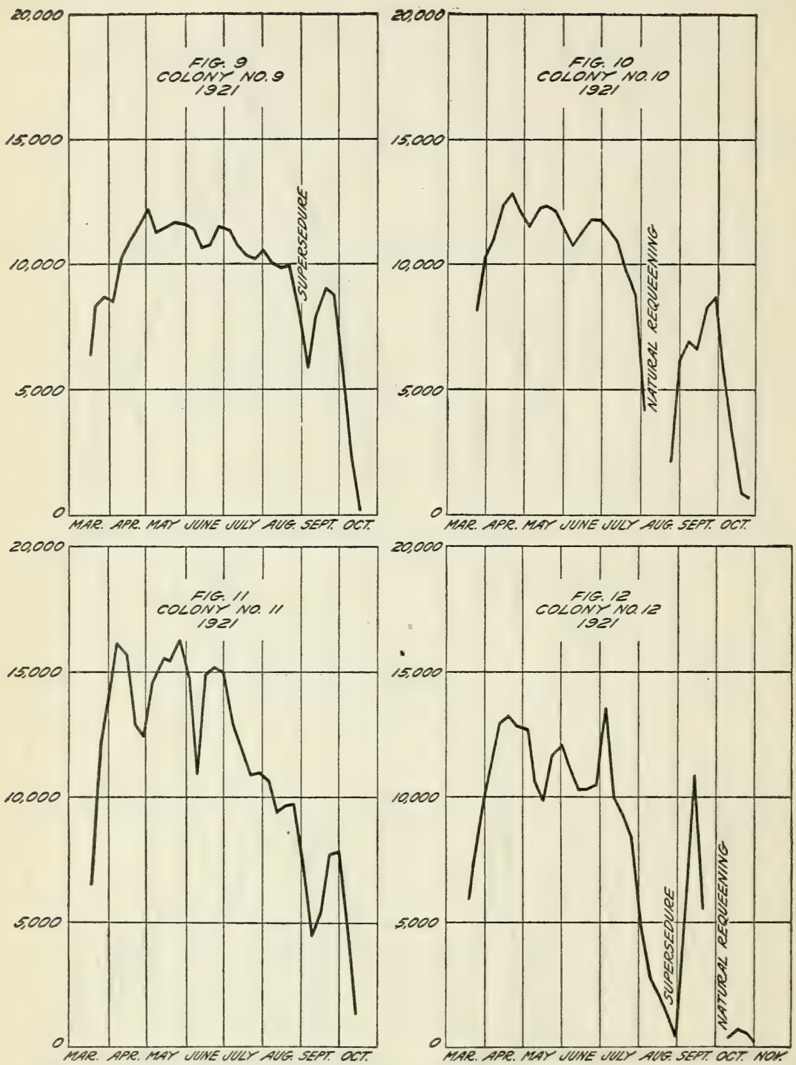
[1] Requeening. [2] No record taken.

GRAPHS

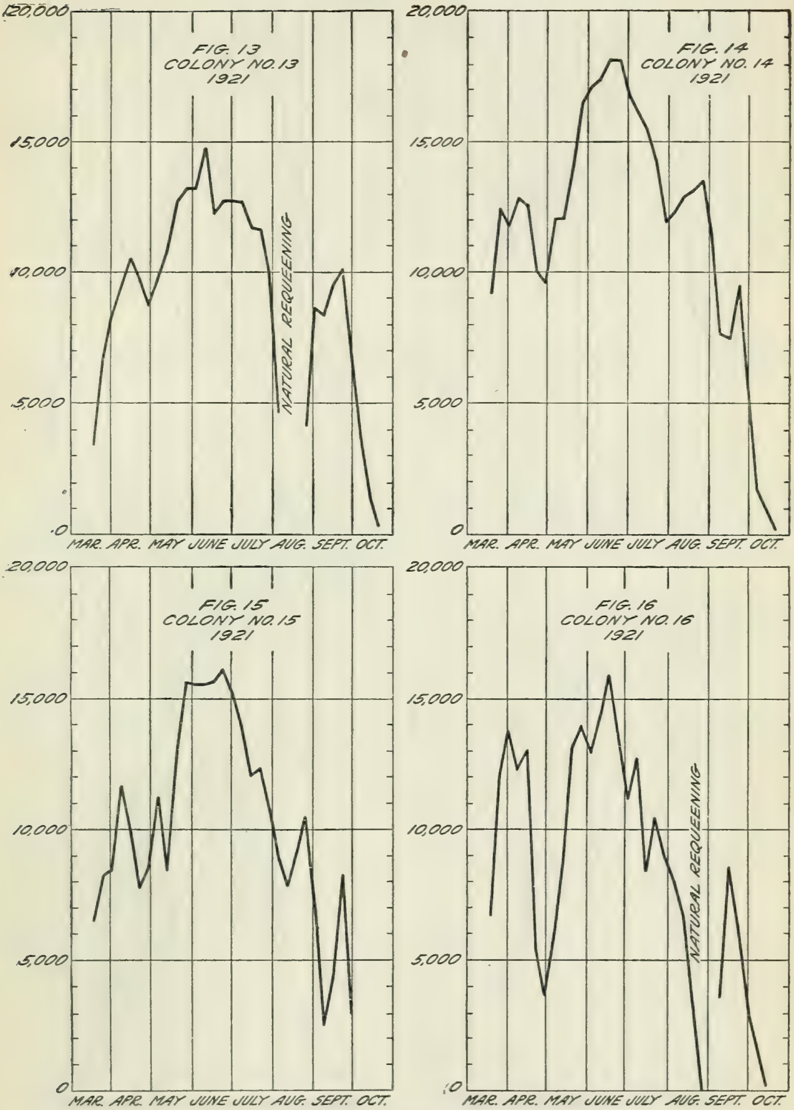


FIGS. 1 to 4.—Curves showing amount of sealed brood found weekly during the season of 1921 in colonies Nos. 1 to 4

FIGS. 5 to 8.—Curves showing amount of sealed brood found weekly during the season of 1921 in colonies Nos. 5 to 8



FIGS. 9 to 12.—Curves showing amount of sealed brood found weekly during the season of 1921 in colonies Nos. 9 to 12



FIGS. 13 to 16.—Curves showing amount of sealed brood found weekly during the season of 1921 in colonies Nos. 13 to 16

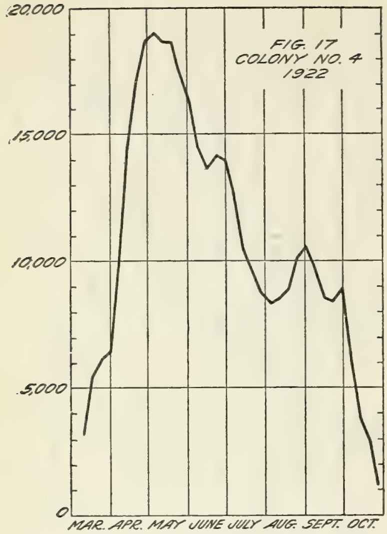


FIG. 17.—Curve showing amount of sealed brood found weekly during the season of 1922 in colony No. 4

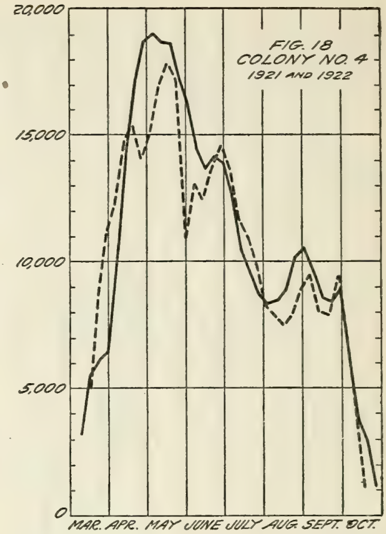
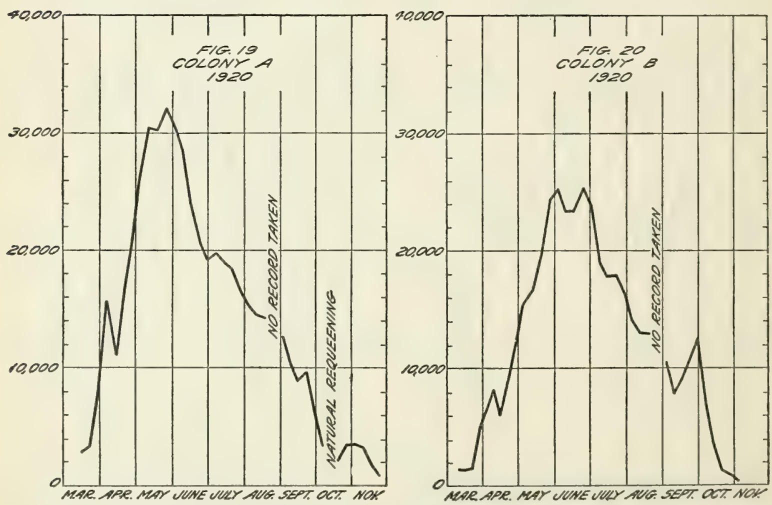


FIG. 18.—Curves showing amount of sealed brood found weekly during the seasons of 1921 and 1922 in colony No. 4. The curve for 1921 is represented by a broken line; that for 1922 by an unbroken line



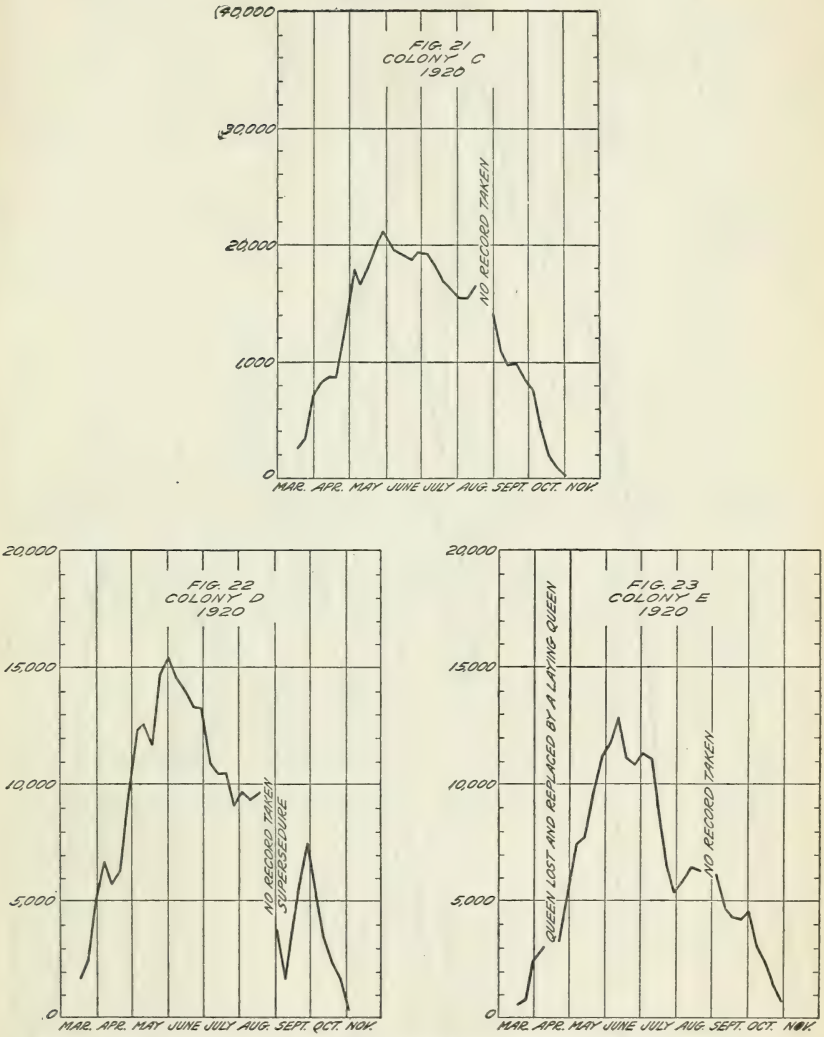
FIGS. 19 and 20.—Curves showing total eggs, unsealed larvæ, and sealed brood found weekly during the season of 1920 in colonies A and B

United States Department of Agriculture

Department Bulletin 1349,
"The Brood-Rearing Cycle of the Honeybee."

Correction Slip

Page 49, figs. 21 to 23. The numbers at the left of the horizontal lines in the graphs should be the same as in Figures 19 and 20, page 48, namely, 40,000, 30,000, 20,000, 10,000, and 0.



FIGS. 21 to 23.—Curves showing total eggs, unsealed larvæ, and sealed brood found weekly during the season of 1920 in colonies C, D, and E

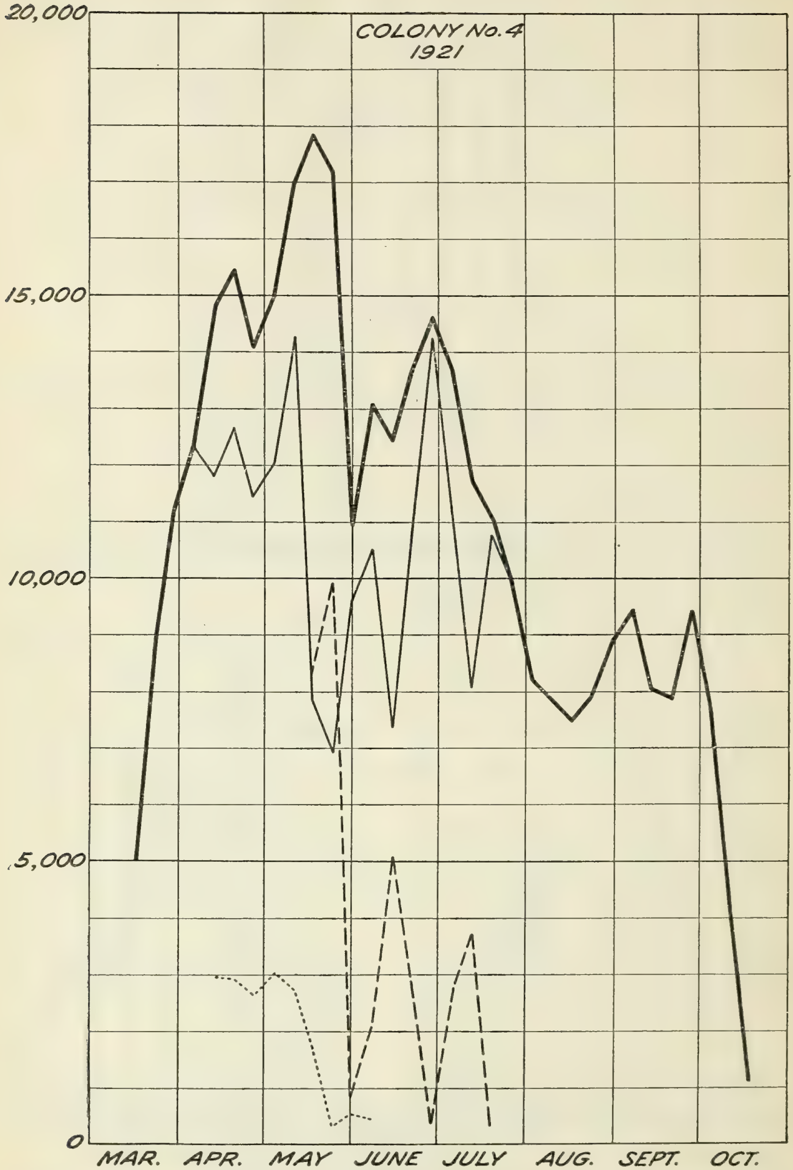


FIG. 24.—Curves showing amount of sealed brood found weekly in the various hive bodies during the season of 1921 in colony No. 4. The heavy unbroken line represents the total of all hive bodies; the dotted line the first, the narrow unbroken line the second, and the narrow broken line the third hive body

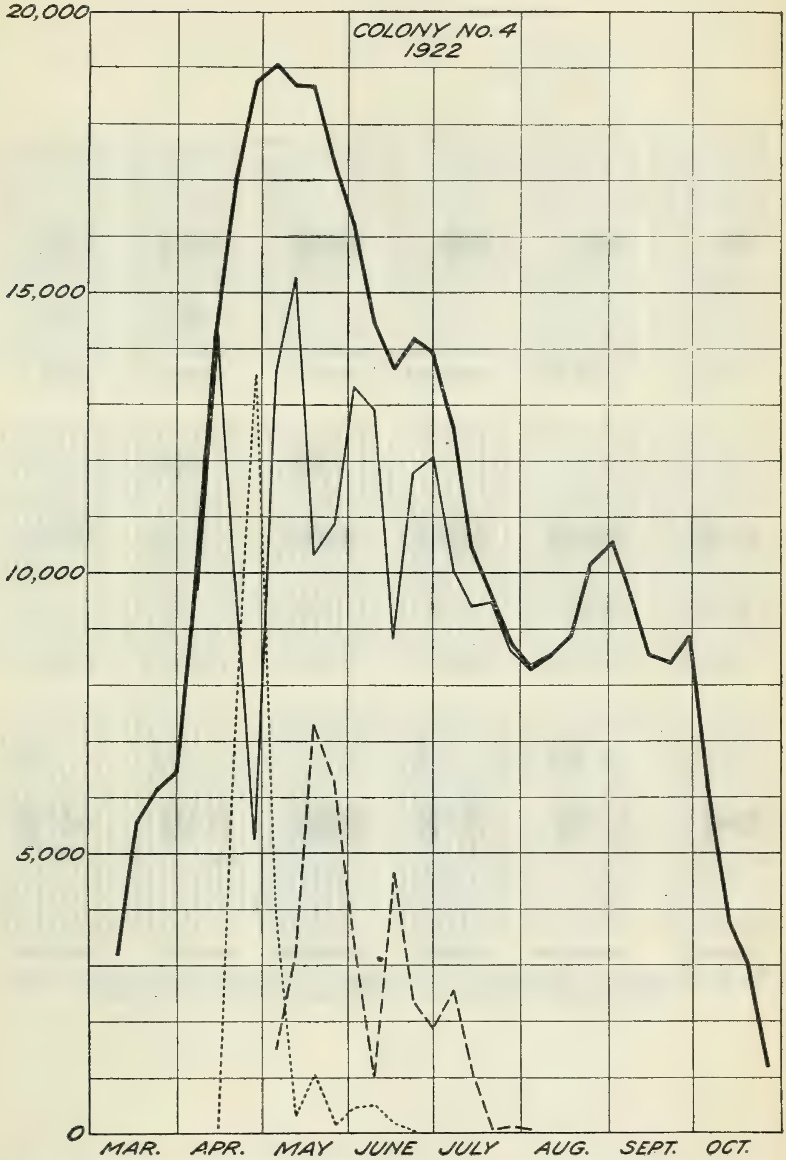


FIG. 25.—Curves showing variation in sealed brood found weekly in the various hive bodies during the season of 1922 in colony No. 4. The heavy unbroken line represents the total of all hive bodies; the dotted line the first, the narrow unbroken line the second, and the narrow broken line the third hive body

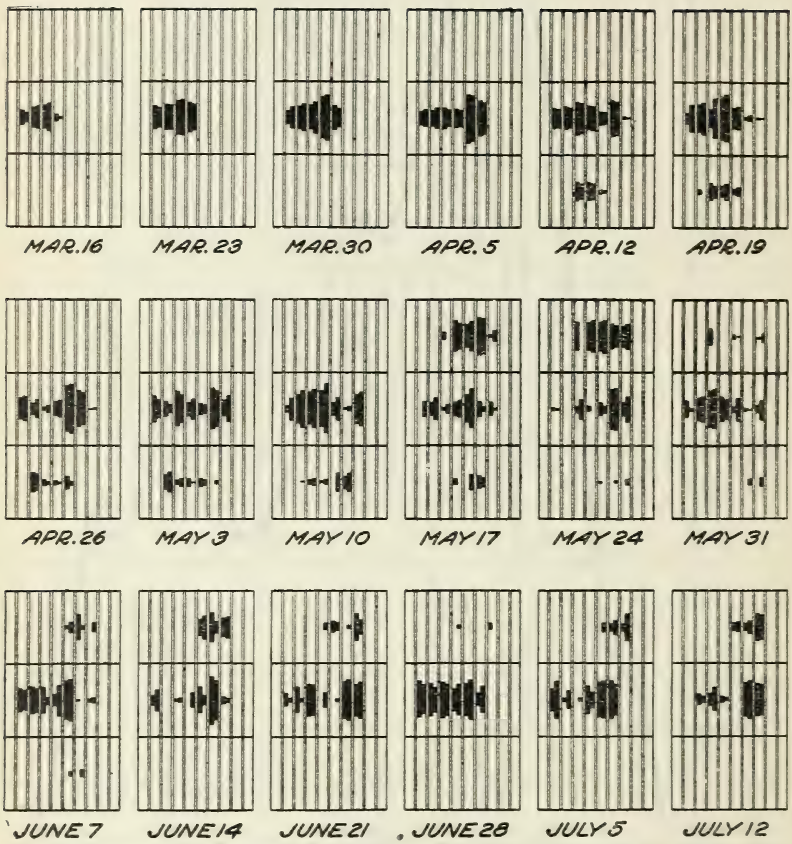


FIG. 26.—Diagrammatic representation of the amount of sealed brood on each side of each frame in the three hive bodies of colony No. 4 from March 16 to July 12, 1921

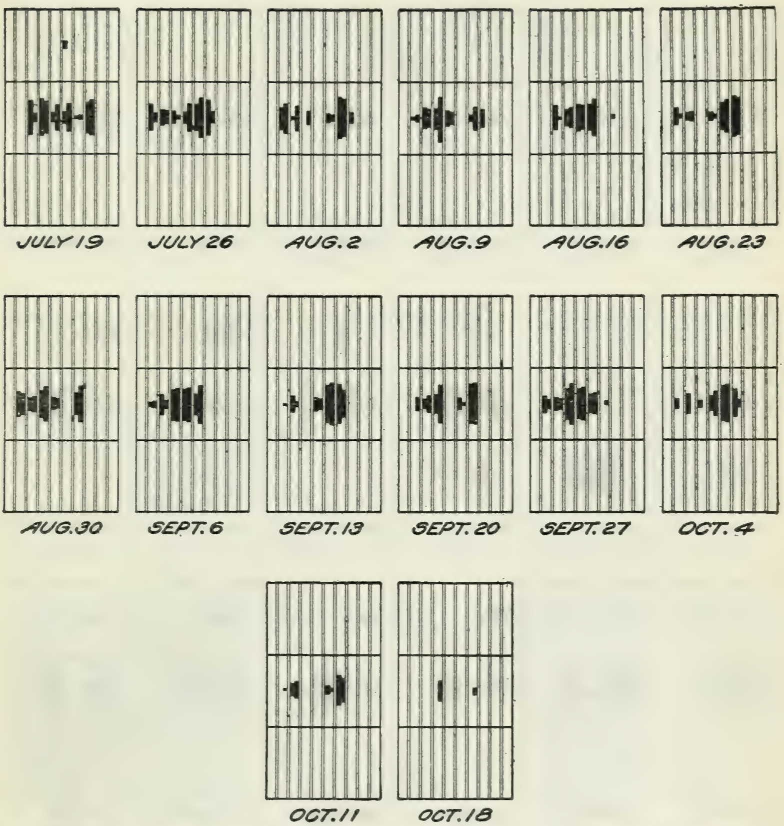


FIG. 27.—Diagrammatic representation of the amount of sealed brood on each side of each frame in the three hive bodies of colony No. 4 from July 19 to October 18, 1921

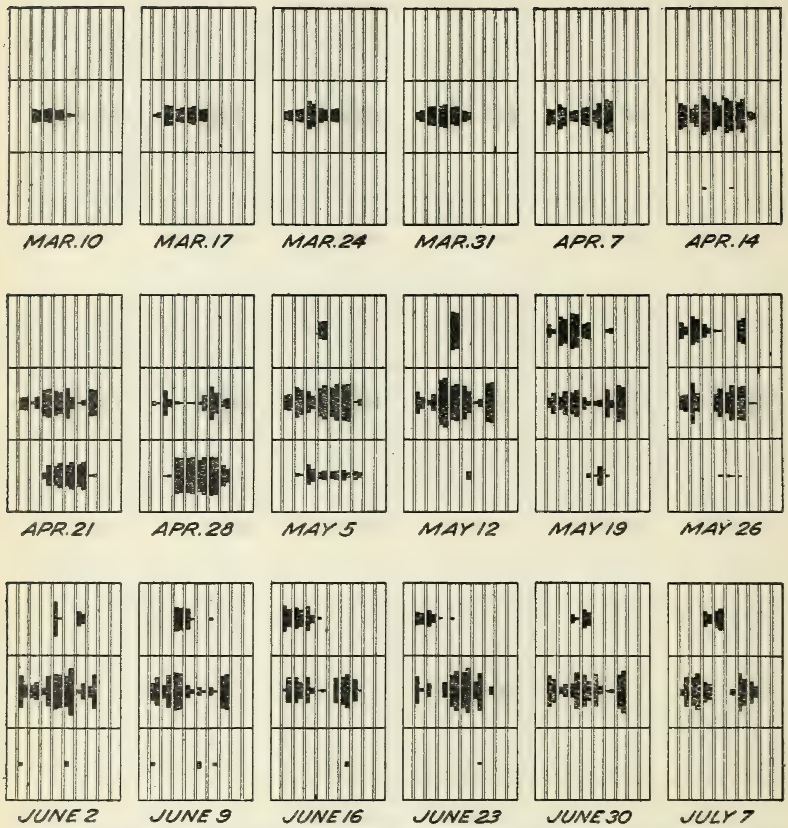


FIG. 28.—Diagrammatic representation of the amount of sealed brood on each side of each frame in the three hive bodies of colony No. 4 from March 10 to July 7, 1922

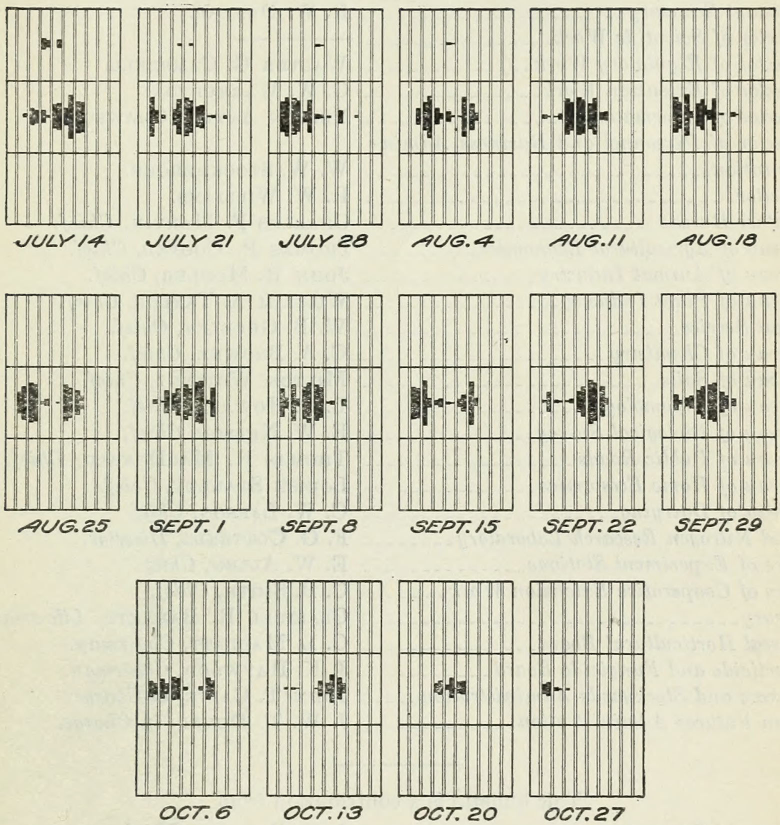


FIG. 29.—Diagrammatic representation of the amount of sealed brood on each side of each frame in the three hive bodies of colony No. 4 from July 14 to October 27, 1922

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

September 8, 1925

Secretary of Agriculture	W. M. Jardine.
Assistant Secretary	R. W. Dunlap.
Director of Scientific Work	———
Director of Regulatory Work	Walter G. Campbell.
Director of Extension Work	C. W. Warburton.
Director of Information	Nelson Antrim Crawford.
Director of Personnel and Business Administration	W. W. Stockberger.
Solicitor	R. W. Williams.
Weather Bureau	Charles F. Marvin, *Chief.*
Bureau of Agricultural Economics	Thomas P. Cooper, *Chief.*
Bureau of Animal Industry	John R. Mohler, *Chief.*
Bureau of Plant Industry	William A. Taylor, *Chief.*
Forest Service	W. B. Greeley, *Chief.*
Bureau of Chemistry	C. A. Browne, *Chief.*
Bureau of Soils	Milton Whitney, *Chief.*
Bureau of Entomology	L. O. Howard, *Chief.*
Bureau of Biological Survey	E. W. Nelson, *Chief.*
Bureau of Public Roads	Thomas H. MacDonald, *Chief.*
Bureau of Home Economics	Louise Stanley, *Chief.*
Bureau of Dairying	C. W. Larson, *Chief.*
Fixed Nitrogen Research Laboratory	F. G. Cottrell, *Director.*
Office of Experiment Stations	E. W. Allen, *Chief.*
Office of Cooperative Extension Work	C. B. Smith, *Chief.*
Library	Claribel R. Barnett, *Librarian.*
Federal Horticultural Board	C. L. Marlatt, *Chairman.*
Insecticide and Fungicide Board	J. K. Haywood, *Chairman.*
Packers and Stockyards Administration	John T. Caine, *in Charge.*
Grain Futures Administration	J. W. T. Duvel, *in Charge.*

This bulletin is a contribution from

Bureau of Entomology	L. O. Howard, *Chief.*
Division of Bee Culture Investigations	J. I. Hambleton, *Apiculturist, in Charge.*

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY
▽